Research production and research collaboration in Zimbabwe: A bibliometric study in context

by

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DECLARATION

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ABSTRACT

Several bibliometric studies on research production and research collaboration in Africa have been carried out. Most of the studies use mainstream bibliographic databases (Scopus and Web of Science [WoS]) as their main sources for bibliometric analysis. Such studies rarely apply context explicitly in bibliometric analysis. In addition, the studies almost exclusively use data sets at article level, with articles as the unit of analysis. The studies also typically regard international research collaboration as the most important measure of international research participation in the African research landscape, with little attention to additional measures adapted to the African context. Finally, existing bibliometric studies on Africa rarely use data from other sources (e.g. surveys or interviews) to reflect on research collaboration. The main goal of this dissertation is to address these limitations within a study on research production and collaboration in Zimbabwe.

To achieve the study goal, a quantitative case study of research production and research collaboration in Zimbabwe was conducted. Two quantitative methods were used to illuminate the specific case: a bibliometric analysis and a web-based survey. Data for the bibliometric analysis were obtained from three bibliographic databases: Scopus, WoS and the National Research Database of Zimbabwe (NRDZ). The NRDZ was added to reflect on the value of using a national research database as an additional bibliometric data source. Although bibliometrics is useful for profiling research collaboration in Zimbabwe, it cannot capture the full range of social dynamics experienced by researchers. Therefore, a web-based survey was conducted to explore other aspects and experiences of research collaboration in order to provide more depth and context to the bibliometric analysis. A database of published researchers (obtained from the bibliometric database) and potentially research-active researchers (obtained from institutional websites) was compiled and used to create a distribution list for the web-based survey.

Patterns of research production and research collaboration of Zimbabwean organisations in the different national sectors and fields, and within four socio-political periods (the context), were profiled. The study also converted an article database into a database of article authors. This enabled the identification of the Zimbabwean research workforce. Not only have the research workforce been identified, but also the collaboration patterns of such researchers (article authors). The author level analysis made possible a comparison between the percentages of articles with research collaboration and the percentages of article authors involved in research collaboration. A comparison of research workers in Zimbabwe (as

bibliometrically identified) with external information about the number of researchers in Zimbabwe provided additional insights.

The study's results have the potential to enrich further bibliometric studies on research collaboration in Africa. It introduced the notion of 'international national organisations' (INOs), which is a new way of measuring international participation in Africa's research. It has also developed a new classification framework of types of authorship that accommodates the phenomenon of INOs as a form of international research participation. This framework not only accommodates the phenomenon of INOs, but can also be used in other bibliometric studies on research collaboration to study authors with dual international affiliations. However, the study's most important contribution is the integration of two mainstream bibliographic databases (Scopus and WoS) to create a new database of Zimbabwean articles, and its supplementation with articles from the NRDZ. Accordingly, recommendations with a view to both further study and research policy were made.

OPSOMMING

Verskeie bibliometriese studies oor navorsingsproduksie en navorsingsamewerking in Afrika is reeds uitgevoer. Die meeste van die studies gebruik hoofstroom bibliografiese databasisse (Scopus en 'Web of Science' [WoS]) as die belangrikste bron vir bibliometriese analise. Sodanige studies pas ook selde konteks eksplisiet toe in die bibliometriese analise. Daarby maak die studies feitlik uitsluitlik gebruik van datastelle op artikelvlak, met artikels as die eenheid van analise. Die studies beskou ook internasionale navorsingsamewerking as die belangrikste maatstaf vir internasionale navorsingsdeelname in die Afrika-navorsingslandskap, met min aandag aan addisionele maatstawwe wat aangepas is vir die Afrika-konteks. Laastens gebruik bestaande bibliometriese studies oor Afrika selde data van ander bronne (bv. opnames of onderhoude) om oor navorsingsamewerking te besin. Die hoofdoel van hierdie proefskrif is om hierdie beperkings van bibliometriese studies binne die konteks van ’n studie oor navorsingsproduksie en -samewerking in Zimbabwe aan te spreek.

’n Kwantitatiewe gevallestudie van navorsingsproduksie en navorsingsamewerking in Zimbabwe is uitgevoer ten einde die studiedoel te bereik. Twee kwantitatiewe metodes is gebruik om die spesifieke geval te belig: ’n bibliometriese analise en ’n webopname. Data vir die bibliometriese analise is verkry uit drie bibliografiese databasisse: Scopus, WoS en die Nasionale Navorsingsdatabasis van Zimbabwe (NNZ). Die NNZ is bygevoeg om te besin oor die waarde van die gebruik van ’n nasionale navorsingsdatabasis as ’n addisionele bibliometriese databron. Alhoewel die bibliometriese metode nuttig is vir die profilering van navorsingsamewerking in Zimbabwe, kan dit nie die volle omvang van sosiale dinamika wat navorsers ervaar, vaslê nie. Daarom is ’n webopname gedoen om ander aspekte en ervarings van navorsingsamewerking te verken ten einde meer diepte en konteks aan die bibliometriese analise te verleen. ’n Databasis van gepubliseerde navorsers (verkry uit die bibliometriese databasis) en potensieel navorsingsaktiewe wetenskaplikes (verkry vanaf institusionele webwerwe) is saamgestel en gebruik om ’n verspreidingslys vir die webopname te skep.

Die patrone van navorsingsuitsette en die patrone van navorsingsamewerking van Zimbabwiese organisasies in die verskillende nasionale sektore en velde, en ook binne vier sosio-politieke tydperke (konteks), is geprofileer. Die studie het ook ’n artikeldatabasis omgeskakel in ’n databasis van artikelouteurs. Dit het die identifikasie van navorsingswerkers in Zimbabwe moontlik gemaak. Nie net is die navorsingswerkers geïdentifiseer nie, maar ook die samewerkingspatrone van navorsers. Die outeursvlakanalise het ’n vergelyking moontlik gemaak tussen die persentasie van artikels met navorsingsamewerking en die persentasies

van artikelouteurs wat by navorsingsamewerking betrokke is. ’n Vergelyking van navorsingswerkers in Zimbabwe (soos bibliometries geïdentifiseer) met eksterne inligting omtrent die getal navorsers in Zimbabwe, het verdere insigte gelewer.

Die studie se resultate het die potensiaal om verdere bibliometriese studies oor navorsingsamewerking in Afrika te verryk. Dit het die verskynsel van ‘internasionale nasionale organisasies’ (INO’s) bekendgestel, wat ’n nuwe manier is om internasionale deelname aan Afrika se navorsing te meet. Dit het ook ’n nuwe klassifikasieraamwerk van tipes outeurskap ontwikkel wat die verskynsel van INO’s as ’n vorm van internasionale navorsingsdeelname akkommodeer. Dit raamwerk akkommodeer nie net die verskynsel van INO’s nie, maar kan ook gebruik word in ander bibliometriese studies oor navorsingsamewerking om outeurs met dubbele internasionale verbintenisse te identifiseer. Die studie se belangrikste bydrae is egter die integrasie van twee hoofstroom bibliografiese databasisse (Scopus en WoS) om ’n nuwe databasis van Zimbabwiese artikels te skep, en die aanvulling daarvan met artikels uit die NNZ. Daarvolgens kan aanbevelings gemaak met die oog op beide verdere studie en navorsingsbeleid.

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LIST OF ABBREVIATIONS

ACFD	Africa Centre for Fertilizer Development
AGRITEX	Agricultural, Technical and Extension Services
AIAS	African Institute for Agrarian Studies
AMA	Agriculture Marketing Authority
AR	Arctic Research
ARC	Agricultural Research Council of Zimbabwe
ARDA	Agricultural and Rural Development Authority
ART	Agricultural Research Trust
AS	Agricultural sciences
AU	Australia
AU-NEPAD	African Science and Technology Consolidated Plan of Action
BHP	Broken Hill Proprietary
BW	Botswana
CA	Canada
CERN	European Organization for Nuclear Research
CeSHHAR	Centre for Sexual Health and HIV AIDS Research Zimbabwe
CGIAR	Consultative Group on International Agricultural Research
CH	Switzerland
CIAT	International Center for Tropical Agriculture
CIFOR	Centre for International Forestry Research
CIMMYT	International Maize and Wheat Improvement Center
CN	China
CNRG	Centre for Natural Resource Governance
COPE	Centre of Publications Ethics
CREST	Centre for Research on Evaluation, Science and Technology
CRDF	Cooperative Research and Development Fund
CSC	Cold Storage Company
CTDT	Community Technology Development Trust
CV	Curricula Vitae
DARE	Database of Abstracts of Reviews of Effects
DE	Germany
DK	Denmark
DRSS	Department of Research and Specialist Services

DVLS	Department of Veterinary and Laboratory Service
EGPAF	Elizabeth Glaser Pediatric Aids Foundation
EMA	Environmental Management Agency
EN	Engineering and Technologies
ESAP	Economic Structural Adjustments Program
FAO	Food and agriculture Organisation
FR	France
FTE	Full-time equivalent
GERD	Gross domestic expenditure on R&D
GDP	Gross domestic product
GMB	Grain Marketing Board
GNU	Government of National Unity
HC	Headcount
HFSP	Human Frontiers Science Program
HGP	Human Genome Project
HIFC	Humanitarian Information Facilitation Centre
HOSPAZ	Hospice and Palliative Care Association of Zimbabwe
HS	Health sciences
HU	Humanities
ICMJE	International Committee of Medical Journal Editor
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IMF	International Monetary Fund
IMS	Intelligent Manufacturing Systems
INO	International national organisations
IPCC	Intergovernmental Panel on Climate Change
IR	institutional repository
ISS	International Space Station
JP	Japan
KE	Kenya
KMO	Kaiser-Meyer-Olkin
KPMG	Klynveld Peat Marwick Goerdeler
LIS	Library and information Science
MACO	Midlands AIDS Caring Organisation
MISA	Media Support
MLN	Maize Lethal Necrosis

MRCZ	Medical Research Council of Zimbabwe
MSF	Doctors without Borders
MW	Malawi
NANGO	National Association of Non-Governmental Organisations
NASW-Z	National Association of Social Workers Zimbabwe
NG	Nigeria
NGOs	Non-governmental organisations
NIHR	National Institute of Health Research
NL	Netherlands
NO	Norway
NRDZ	National Research Database of Zimbabwe
NRF	National Research Foundation
NS	Natural sciences
NSIMA	New Seed Initiative for Maize in Southern Africa
OA	Open Access
ODP	Ocean Drilling Program
OPC	Office of the President and Cabinet
PCA	Principal Component Analysis
PIB	Pig Industry Board
PL	Poland
PPRIZ	Public Policy Research Institute of Zimbabwe
PSC	Public Service Commission
PSI	Population Services International
R&D	Research and Development
RCZ	Research Council of Zimbabwe
REC	Research Ethics Committee
RoA	Rest of Africa
RoW	Rest of World
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
S&T	Science and Technology
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SIRDC	Scientific and Industrial Research and Development Centre
SLO	Scientific and Liaison Office
SOFECSA	Soil Fertility Consortium for Southern
SS	Social sciences

STI	Science, technology and innovation
SWOT	Strengths, Weaknesses, Opportunities and Threats
SZ	Swaziland
TARSC	Training and Research Support Centre
TMB	Tobacco Marketing Board
TNO	True National Organisation
TRB	Tobacco Research Board
TSP	Transitional Stabilisation Programme
TVET	Technical and Vocational Education Training
TZ	Tanzania
UDCORP	Urban Development Corporation
UG	Uganda
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children's Fund
USA	United States of America
UZ-CRC	University of Zimbabwe Clinical Research Center
VSO	Volunteer Zimbabwe, Volunteering and charity work in Zimbabwe
WASN	Women and AIDS Support Network Zimbabwe
WHO	World Health Organisation
WOS	Web of Science
ZA	South Africa
ZACRO	Zimbabwe Association for Crime Prevention and Rehabilitation of the Offender
ZADHR	Zimbabwe Association of Doctors for Human Rights
ZAOGA	Zimbabwe Assemblies of God Africa
ZELA	Zimbabwe Environmental Law Association
ZIDS	Zimbabwe Institute of Development Studies
Zim-Asset	Zimbabwe Agenda for Sustainable Socio-Economic Transformation
ZIMCHE	Zimbabwe Council of Higher Education
ZIMSTAT	Zimbabwe National Statistics Agency
ZM	Zambia
ZWRCN	Zimbabwe Women's Resource Centre and Network

CHAPTER 1
Introduction

1.1 Background

Africa's scientific research output as compared to that of the rest of the world has always been low. For instance, Tijssen (2007) reported on a decrease in sub-Saharan Africa's contribution to world science output from 1% in 1987 to 0.7% in 1996; and Pouris and Pouris (2009) reported Africa's share to be 1.8% for the period 2000-2004. The relatively low output has been attributed to several factors including the absence of a local index of knowledge, unequal criteria for knowledge inclusion in mainstream indexes, lack of research capabilities, limited funding, poor research infrastructure, and continued brain drain (Ishengoma, 2016; Nwagwu, 2007; 2012; Varshney et al., 2016). However, more recent bibliometric studies have shown that the tide has since turned, and Africa's scientific output has started to increase. For example, Mouton and Blanckenberg (2018) show that Africa's annual output has been steadily increasing over the past decades – from 15 285 in 2005 to 54 069 in 2016. What is most striking, as noted by Mouton and Blanckenberg, is that the continent's share of world publication output doubled from 1.5% in 2005 to 3.2% in 2016, surpassing the world growth rate during that same period.

Concerning research collaboration, bibliometric studies report an increase in the number of articles produced through co-authorship (e.g. studies by Adams et al., 2014; Boshoff, 2010; Guns & Wang, 2017; Mouton & Blanckenberg, 2018; Sooryamoorthy, 2017). There is little co-authorship between African countries, with preference being given to collaboration with researchers from high-income countries (Confraria et al., 2020; Guns & Wang, 2017). This preference is steered by a need to gain access to research infrastructure and funding, and to build research capacities and scientific networks (Confraria et al., 2020). Ishengoma (2016) argues that many of Africa's research and development (R&D) organisations, specifically institutions of higher education, rely on foreign funding for their R&D performance. Because of low funding for research, researchers in most of Africa's higher education institutions often have no choice than to seek collaboration with researchers from high-income countries.

Collaboration among African countries is weak (Adams et al., 2013; Boshoff, 2009; Guns & Wang, 2017). Furthermore, in instances where African countries do collaborate, the collaboration often involves a non-African country as well (Boshoff, 2009), or is mediated through cooperative health and agricultural initiatives (Adams et al., 2014). In terms of the production of research articles, Onyancha and Maluleka (2011) report that sub-Saharan African countries contribute very little to each other’s knowledge production. Adams et al. (2010) refer to the landscape of research collaboration in Africa as extremely complex, where the landscape depends on perspective as well as available data on research collaboration. For instance, Onyacha and Maluleka (2011) argue that collaboration within Africa is remarkably regional, which means researchers collaborate with others within their respective regions. Boshoff (2010), on the other hand, comments on the stronger cross-regional links between South Africa and countries like Kenya and Nigeria rather than with countries in the Southern African Development Community (SADC). Nigeria is also linked not to its geographic West Africa region but to co-Anglophone East Africa (Adams et al., 2010).

Even though several bibliometric studies of research collaboration have been performed for various parts of Africa, both country-wise (e.g. Ghana – Owusu-Nimo & Boshoff, 2017; South Africa – Sooryamoorthy, 2009) and regionally (e.g. Central Africa – Boshoff, 2009; Southern Africa – Boshoff, 2010; West Africa – Mêgnigbêto, 2013; sub-Saharan Africa – Onyancha & Maluleka, 2011), no in-depth study has ever been conducted for Zimbabwe. The results of previous studies on research collaborations in other countries cannot necessarily be generalised to Zimbabwe. This is the case, as noted by Bozeman and Boardman (2013), who argue that even though research collaboration is ubiquitous, evidence suggests that collaboration dynamics vary greatly across nations, institutions, fields, purposes and even individual research teams. Aspects of research production and research collaboration by players in the Zimbabwean research system have not yet been fully explored. Scholarly insight into the phenomenon has the potential to inform the country’s research policy and it can aid policy makers in making informed decisions about allocation of resources.

Zimbabwe is a landlocked country located in Southern Africa, which has been faced with significant socio-political challenges since its independence (Beseda & Moyo, 2008). As research collaboration does not occur in a vacuum, it has and always will be impacted on by Zimbabwe’s socio-political conditions, thereby making Zimbabwe an interesting case for a bibliometric study of research production and research collaboration. (Chapter 2 provides an overview of the context of research in Zimbabwe.)

Other than the current study being the first in-depth bibliometric study about research production and research collaboration in Zimbabwe, the study also aimed to address certain limitations in current bibliometric studies about African research. It needs to be stated upfront that it was not the intention of the study to ‘solve’ the limitations as presented in the next section, because the limitations can only be solved through an accumulation and critical mass of bibliometric studies. Having said that, the current study did intent to steer the first in-depth bibliometric analysis of Zimbabwean research towards demonstrating at least a sensitivity for the limitations and to address each in a specific way as outlined in Section 1.3.

1.2 Problem statement

By paying close attention to the methods and approaches followed in existing bibliometric studies about Africa's research, five 'gaps' could be identified, which collectively constitute the problem statement (together with the fact that no comprehensive bibliometric study has ever been conducted for Zimbabwe):

1. The studies use mainstream bibliographic databases as the main data source for bibliometric analysis;
2. The studies seldom explicitly apply context in the bibliometric analysis;
3. The studies almost exclusively rely on article-level datasets with articles as the units of analysis;
4. The studies treat international research collaboration as the single most prominent measure of international research participation in the African research landscape, with little consideration paid to additional measures tailored for the African context; and
5. The bibliometric studies seldom incorporate data from other sources (e.g. surveys or interviews) to reflect on research collaboration.

Each of the above limitations is briefly elaborated on next, as informed by observations of the relevant bibliometric literature. A first observation made is that bibliometric studies on research collaboration in Africa persistently **use mainstream bibliographic databases** (i.e. Scopus and Web of Science) as their main data sources. This preference could be attributed to two main reasons. Firstly, the databases are seen as comprehensive, covering all fields of science. Secondly, journals indexed in mainstream databases are considered synonymous with international quality standards and are perceived by the academic world as key 'authorities' with the power to identify what universally matters in science (Chavarro Bohórquez, 2016). The Web of Science (WoS), for example, is considered the gold standard for bibliometric studies (Thompson & Walker, 2015). Scopus, on the other hand, is reported to be the largest database for scientific literature in all disciplines, covering about 84% of WoS journal titles in addition to its own, unique coverage (Gavel & Iselid, 2008).

Although mainstream databases are frequently used to report on African science, such databases are not always a true representation of research conducted in the continent, primarily because African scientists tend to publish in local journals. According to Hedt-Gauthier et al. (2019) and Muriithi et al. (2018), researchers prioritise research that addresses local needs such as poverty, food security and disease control. Such research is published in local journals and does not find its way into international mainstream journals. In addition, Gaillard (1992), who almost two decades ago analysed the research output of African and other developing country researchers, concluded that publishing in local journals is a matter of choice. This choice is exercised when research is perceived to have direct application for local stakeholders.

Bibliometric studies that exclude local journals by only focussing on publications in mainstream journals can result in biased conclusions, as some indicators and statistics differ according to whether mainstream or local sources are used. For example, Boshoff and Akanmu (2017) noted differences in indicators of domestic and international collaboration for a faculty of Pharmacy at a Nigerian university when comparing three sources, namely, Scopus, WoS and data derived from the curricula vitae (CVs) of faculty staff. They found that the share of the faculty's international collaboration was highest (36%) when only WoS data was used. It decreased to 31% when Scopus data was added and even further reduced to 28% when CV data was incorporated. The study concluded that relying on WoS data alone would misrepresent the state of affairs at the faculty. In an early study, Shrum (1997) compared the visibility of scientists in the developing world in international bibliographic databases and self-reported measures. He found that self-reported measures yielded 2.7 times more productivity than the bibliometric measures did. The low representation of African scientists in international bibliographic databases led Shrum to conclude that bibliometric studies based on mainstream bibliographic databases could not accurately represent African science. Without fully discarding the use of mainstream databases to study research output in Africa, combining the databases with other sources (e.g. local journal and national/institutional repositories) would give more comprehensive results.

The second observation about gaps in the existing literature is that bibliometric analyses of African research seldom explicitly **apply context in the analysis**. Context as defined in the Cambridge English dictionary is "the situation within which something exists or happens, and that can help explain it".[1] In bibliometric studies, an argument can be made that context is

[1] https://dictionary.cambridge.org/dictionary/english/context

either applied or constructed. Applying context in bibliometric studies, for instance, would mean the use of contextual information or information about the setting in which research takes place (e.g. the social, institutional and technical environments) to develop appropriate analytical categories to be used in the analysis. Constructing context, on the other hand, as the word depicts, means generating (or revealing) context through new bibliometric findings. The latter findings then provide context for other studies. Although it can be argued that all bibliometric studies generate context and therefore are not context free, the focus in this study is on the *application* of context in bibliometric analysis. Most bibliometric studies of African research seldom apply context in the analysis. In instances where context is applied, it is done either in the introduction to a study, where relevant R&D indicators or the prevailing research environment are discussed, or in a discussion of the profile of research systems and research organisations (e.g. Mêgnigbêto, 2013; Owusu-Nimo & Boshoff, 2017). Notably absent is the incorporation of context in the analytic sections of a study (e.g. analysing data in terms of a classification framework that mirrors the relevant conditions in a country or region). In some instances, context only appears in the discussion section to explain the patterns of research production and collaboration. For example, in their discussion sections, Adams et al. (2014) and Mêgnigbêto (2013) argued that language, historical ties and culture shaped regional and international collaboration patterns. Adams et al. (2014) showed that while France was more linked to its former French-speaking colonies in North-West and Central West African countries, the UK also had strong ties with its former English colonies in East and Southern Africa. Large projects such as the country studies on science, technology and innovation commissioned by the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2014, 2015) profile context. However, in most reports (i.e full reports as opposed to journal articles), context appears in its own chapters and is not incorporated in the data analysis. A few studies (e.g. Confraria et al., 2020; Owusu-Nimo & Boshoff, 2017) accommodate context in their bibliometric data in a different way, that is by combining bibliometric data with survey data as a source of context that is based on self-reporting data (this approach is elaborated on in the last part of this section).

Various authors have noted the importance of including context in analyses of research output and collaboration. Muriithi et al. (2018), for instance, remark that collaborative research depends on the context within which research is conducted, including social, institutional, and technical environments. These environments differ according to regions, countries, institutions, fields, and even individual research teams. Similarly, Sugimoto and Lariviere (2018) noted that although bibliometric data analysis provides insights into research systems (i.e. research output and co-authorship patterns), such analysis is best understood within a country's unique context. Context is important in the African context. As elsewhere in the world, countries went through different socio-economic and political challenges in their independence phase, which, in turn, shape the status quo of science and provide explanations of research output and research collaboration.

The third observation made is that most bibliometric studies on African science use **articles as the main unit of analysis**. Bibliometric studies could focus on the research that is produced (i.e. articles and their characteristics) or on those responsible for producing the research (i.e. article authors and their characteristics). However, most bibliometric studies use the former as the main unit of analysis. This is despite the fact that individual researchers, and not their articles, are the real sources of research activity. Individual researchers constitute the scholarly research workforce of a country as they contribute to original research in scholarly journals. Individuals are associated with departments, research groups, institutions, sectors and countries. Individual-level analysis can be applied to measure the productivity and networks of the research scholarly workforce, and can also be used to track the mobility of that workforce.

Individual-level bibliometrics is a recent phenomenon in research measurement and has not yet been widely applied especially in bibliometric studies on research collaboration in Africa. Although quite recent, an example of an author-level bibliometric study for a developing country is provided by Boshoff et al. (2018), who identified Ugandan internationally-linked authors by focusing on four overlapping groups of internationally-linked authors; namely, authors with an international co-author, authors with a joint international affiliation, authors affiliated with an international organisation that has a local address, and authors affiliated with an international research partnership. Boshoff and his colleagues observed that the most productive Ugandan authors were a small group who recorded all four aforementioned forms of international linkages. In their conclusion, Boshoff et al. (2018) recommended the exploration of different units of analysis such as author-level datasets tailor-made for specific countries.

Another bibliometric study that used the individual as the unit of analysis is that by Hedt-Gauthier et al. (2019). Hedt-Gauthier and his team compiled both author-level and article-level datasets to investigate how international collaborations affect the representations of local authors in first- and last-place author positions, focussing on African health research. They found that collaborating with researchers in high-income countries decreased local representation, particularly in first and last positions; in other words, in terms of authorship in health research, African scientists did not take up leadership positions. The authors attributed this to the fact that compared to researchers in low-income countries, those in high-income countries have technical advantages; greater economic and academic resources, including extensive institutional infrastructure to lead project administration; and stronger research networks, including greater representation on journal editorial boards. Hedt-Gauthier et al. also found that collaborating with individuals from other African institutions increased local representation in published articles, and that these collaborations tended to focus on research priorities in Africa. However, a negative consequence of intra-African collaborations was that such articles were less likely to be cited (ibid.).

The fourth observation about gaps in the existing literature is that bibliometric studies (e.g. by Adams et al., 2014; Boshoff, 2009; Boshoff, 2010; Confraria et al., 2020; Mêgnigbêto, 2013; Owusu-Nimo & Boshoff, 2017; Pouris & Ho, 2014) often treat international research collaboration as the single most prominent (if not only) **measure of international research participation** in the African research landscape. In other words, these studies typically measure international research collaboration based on bibliometric analyses of international co-authorship. Recently, with the availability of data on the funding acknowledgements of articles, reflections on the nature and extent of international funding have paved the way for new bibliometric measures of international involvement in research (e.g. studies by Kozma et al., 2018; Wang & Shapira, 2011; Paul-Hus et al., 2016). What seems to be overlooked in bibliometric studies in Africa is the phenomenon of 'international national organisations' (INOs) as another form of international participation in Africa's research. INOs are defined here as international organisations or initiatives of international organisations (or sets of organisations) that use an African country address in their publications. INOs tend to be adapted to the host country by supporting the research goals and research agendas of those countries. While they appear to be national organisations, they are in fact international organisations 'masquerading' as national organisations. In bibliometric studies of African countries, INOs can be coded erroneously as national organisations as they do not report their international addresses in publications but addresses of African host countries. Focussing on Zimbabwe, these INOs can be disaggregated into the following four forms:

1. Inter-governmental organisations that use a Zimbabwean address for publication instead of their (international) base address – Food and agriculture Organisation (FAO), World Health Organisation (WHO) and the World Bank.

2. International non-governmental organisations that use a Zimbabwean address for publication instead of their (international) base address – The Elizabeth Glaser Pediatric Aids Foundation (EGPAF), World Vision and Doctors without Borders (MSF).
3. Partnerships of international research centres that use a Zimbabwean address for publication instead of their (international) base address – Consultative Group on International Agricultural Research (CGIAR) centres such as the Centre for International Forestry Research (CIFOR) with its headquarters in Indonesia; International Crops Research Institute for Semi-Arid Tropics (ICRISAT), headquartered in India; and International Maize and Wheat Improvement Center (CIMMYT), headquartered in Mexico.
4. International businesses that use a Zimbabwean address for publication instead of their (international) base address – Seed-Co, Ernst & Young, Deloitte, KPMG and PricewaterhouseCoopers.

The organisations mentioned above use local addresses in publications although they have a strong international origin. All INOs are headquartered outside the host countries but report a local country address in publications. Two examples will suffice, namely that of the CGIAR and the WHO.

The CGIAR network has five of its 15 centres headquartered in sub-Saharan Africa, with the rest outside of Africa. The CGIAR network was established to create agricultural science centres of excellence to deal with food insecurity and related agricultural development issues, especially in the poorest countries of the world. CGIAR brings evidence to policy makers; innovation to partners; and new tools to harness the economic, environmental and nutritional power of agriculture[2] (CGIAR, 2020). The staff at the individual CGIAR centres “have no larger organizational home beyond their own center” (Herdt, 2012, p. 188). Each centre has its own charter, board of trustees and staff. The centres appear to be an ideal instrument for developing a stream of new agricultural technology. They have long been ‘qualified’ to receive foundation grants; they have outstanding leadership and staff who can write good proposals; they have research facilities in the poorest developing countries; and they have access to local agricultural researchers (Herdt, 2012, p. 187).

The WHO as another example operates in more than 150 countries around the world and has its headquarters in Geneva, Switzerland. It has a system of country regional and country

[2] CGIAR website: www.cgiar.org, accessed March 2020.

offices with WHO representatives heading those offices. The WHO conducts research directly through its own staff but also commissions research to external researchers (Terr & Van der Rijt, 2010). Commissioned research can take the form of contract research where the WHO defines the research question, or the form of grants to institutions, fellowships and individuals. At times the WHO also guides or advises research by being part of a network or partnership. Its main areas of work in Africa include health sector development and combating infectious and non-infectious diseases.

In conclusion, INOs present a second type of international research participation in Africa (next to international research collaboration), and can involve both academics and non-academics. Examples of non-academics include staff at international non-governmental organisations (NGOs), among which multilateral aid agencies. INOs provide a new measure of international involvement, especially in the African context where most institutions rely on foreign support for research. It is important to emphasise that *INOs are first and forestmost international organisations* established under global treaties and other international arrangements. However, they do manifest as INOs in cases where their research is presented as the national output of an African country, specifically when they publish by using the address of an African country and not their headquarter country.

The last observation made is that most bibliometric articles seldom incorporate **other data sources to reflect on research collaboration** (e.g. survey or interview data). The few studies that report different methods are large projects such as the Young Scientists in Africa study conducted by the Centre for Research on Science and Evaluation at Stellenbosch University (CREST, 2018), and a study on the state of public science in the Southern African region (CREST, 2007). The Young Scientists project, for example, employed bibliometrics, a web-based survey and a series of qualitative interviews for an in-depth analysis of Africa's scientific production and networks, with a focus on emerging scientists in the region. Such large projects are often commissioned studies, and thus may not necessarily end up in journal publications. Other reports of this nature are country studies on science, technology and innovation commissioned by UNESCO (e.g. UNESCO, 2014, 2015).

However, in contrast with commissioned reports, journal publications that report bibliometric analyses seldom include additional data sources other than the sources of bibliometric data. A few exceptions are studies by Confraria et al. (2020), and Owusu-Nimo and Boshoff (2017). Both these articles incorporated self-reported survey data into the bibliometric analysis. One reason why bliometric studies appear to be stand-alone studies (i.e. not blended with other data sources) is because bibliometric data are relatively easy to access and analyse (Katz & Martin, 1997). An additional justification for the over-reliance on bibliometrics in studying research collaboration stems from the fact that significant contributions to science appear in published research (the key focus of bibliometric studies). However, bibliometric studies essentally highlight co-authorship analysis which might not be the same as actual research collaboration (Lee & Bozeman, 2005). Smith and Katz (2000, p. 12) warn that using co-authorship as a measure of collaborative activity must be treated with caution because:

> “there are many cases of collaboration that are not consummated in a co-authored paper and which are consequently undetected with this approach. Conversely, there are other cases of, at best, only very peripheral or indirect forms of interaction between scientists which nonetheless yield co-authored publications”.

While a bibliometric analysis is useful for understanding collaborations in general, such measures are not able to capture the full range of social dynamics experienced in research collaborations (Tsai et al., 2016). Studies on research collaboration benefit from the use of multiple methodologies, rather than a single approach. This might mean blending bibliometrics with surveys and interview methods. Such methods allow for the exploration of details about collaboration patterns and experiences not captured by bibliometric analysis.

1.3 Aim and methodology of the study

In the previous section, I identified five limitations of current bibliometric studies of research in Africa. The main aim of this dissertation was to address those gaps within the context of a study on Zimbabwean research. Table 1.1 illustrates the issues identified and how they are addressed in this dissertation.

Table 1.1: Research gaps with current bibliometric studies of research in Africa

Five research gaps	How each gap is addressed in this dissertation
Bibliometric studies of African research rely on mainstream databases	This study did not rely on a single mainstream database but on two such databases (WoS and Sopus) for the analysis of research production and research collaboration in Zimbabwe. The two databases have been integrated and unified to create a new database of Zimbabwean articles, and supplemented with articles from the National Research Database of Zimbabwe (NRDZ). The latter is a national, non-mainstream data source.
Bibliometric analyses of African research seldom apply context in the analysis	Following independence in 1980, Zimbabwe underwent a series of events that negatively affected all societal sectors, including human capital and R&D. Therefore, this study incorporated context into the analysis by developing a socio-political timeframe and using that frame to study trends in the data over time. Additional context is also provided by soliciting from Zimbabwean researchers their responses to various aspects of research collaboration through a survey.
Bibliometric studies rely on article-level datasets	In addition to creating a database of articles, the study also converted that database into a novel database of article authors. This allowed, for instance, for a comparison between the shares of articles with collaboration and the shares of article authors involved in collaboration.
Bibliometric studies treat international research collaboration as the single most prominent measure of international research participation in the African research landscape, with little attention to additional measures tailored for the African context	The study introduces a new measure of international research participation in Africa's research, by focusing on the so-called 'international national organisations' (INOs).
Bibliometric studies of African research seldom incorporate other data sources to reflect on research collaboration (e.g. survey or interview data)	The study conducted a survey of research collaboration and related activities in Zimbabwe. The survey allowed for the exploration of details about collaboration patterns and experiences that are not captured by bibliometric analysis.

1.4 Objectives of the study

Given the gaps in bibliometric studies of African research, the study had the following research objectives:

- To determine how the profiles of research production and research collaboration in Zimbabwe differ based on the data sources that are used (i.e. Scopus, WoS and the National Research Database of Zimbabwe [NRDZ]);
- To determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed as compared to when author-level datasets are analysed;
- To introduce a focus on INOs in bibliometric studies by developing a new classification framework of authorship types that accommodates the phenomenon of INOs as a form of international participation, and applying it to Zimbabwe's research; and

- To explore the value that context adds to the bibliometric analyses of Zimbabwe's research production and collaboration, where 'context' is dealt with in two ways – firstly, by analysing the bibliometric data within time periods that are rooted in socio-political reality, and, secondly, by supplementing the bibliometric data with survey data.

Each of the above objectives are associated with a series of specific research questions. These research questions, together with the broad objectives, are presented in Table 1.2.

Table 1.2: Research objectives and research questions of the study

Study objectives	Research questions
To determine how the profiles of research production and research collaboration in Zimbabwe differ based on the data sources that are used (i.e. Scopus, WoS and the NRDZ).	• Based on a combined Scopus and WoS database, what are the nature, extent and patterns of research collaboration in Zimbabwe, as measured through article co-authorship, between 1980 and 2016? • What value does the NRDZ add to a combined Scopus and WoS dataset?
To determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed as compared to when author-level datasets are analysed.	• How do profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed as compared to when author-level datasets are analysed?
To determine the contribution of INOs in Zimbabwe research by developing a classification framework of authorship types that accommodates the phenomenon of INOs as a form of international participation in Zimbabwe's research.	• What is the contribution of INOs to research in Zimbabwe during the period 1980–2016? • What changes are to be observed when applying a new classification framework of authorship types to research in Zimbabwe for the period 1980–2016?
To explore the value that context adds to the bibliometric analyses, where 'context' is dealt with in two ways – firstly, by analysing the bibliometric data within time periods that are rooted in socio-political reality, and, secondly, by supplementing the bibliometric data with self-reporting survey data on various aspects of collaboration and research as experienced by Zimbabwean researchers.	• How do the nature and patterns of research collaboration in Zimbabwe vary across the country's socio-political environment between 1980 and 2016? • What are the reasons for research collaboration and how do these differ according to gender, age, field, sector, and career stage? • What challenges are faced by researchers in Zimbabwe when engaging in research collaboration? How do these challenges differ according to gender, age, field, sector, and career stage? • What examples of authorship disputes do researchers in Zimbabwe experience? How do these disputes come about and how are they resolved?

To answer the above questions, a quantitative research design was employed. The quantitative methods used were the bibliometric method and a web-based survey. Data for the bibliometric analysis were obtained from three bibliographic databases (i.e. Scopus, WoS and the NRDZ). A database of published researchers (bibliometric database) and potentially research-active scholars (websites) was compiled and used to generate a distribution list for the web-based survey. A total of 259 valid responses were received. The questionnaire consisted of closed and open-ended questions. The open-ended questions had some qualitative aspects that supplemented the quantitative data.

Before presenting an outline of the rest of the dissertation, it is deemed necessary to make explicit what the bibliometric analyses did not cover. Firstly, the study did not aim to measure research collaboration by means of a statistical formula to produce a single value that is reflective of collaboration, such as the collaborative coefficient (Savanur & Srikanth, 2010). Rather, the study used the proportion of multiple authored papers (i.e. degree of collaboration) and the mean number of authors per paper (i.e. collaborative index) to measure the extent of collaboration in different fields and sectors, and to highlight the patterns and trends of collaboration. Secondly, the study excluded analyses of authorship positions in articles, i.e. the representation of Zimbabwean researchers in first and last place author positions. The reason for this was because of disciplinary differences in the order of article authorship. Some fields such as mathematics and economics commonly use the alphabetical order of surnames to allocate article authorship positions. Laboratory-based disciplines such as biomedical sciences regard the last-author position to be the most important, whereas in some other disciplines the last-author position is considered the least important (Youtie & Bozeman, 2016

1.5 Outline of the dissertation

The dissertation is structured as follows:

Chapter 2 (“Context of research in Zimbabwe”) provides a historic overview of the science landscape in Zimbabwe. It discusses the state of Zimbabwe’s science system while under colonial rule, and how the country compared with other countries in the region (i.e. in terms of R&D) during that period. The chapter illustrates the three components (i.e. governance, intermediaries, and R&D performers) that constitute the current science system of Zimbabwe. It then discusses the country’s framework for research investment and innovation, as well as its research and innovation capacity. Finally, it provides an overview of the socio-political landscape of Zimbabwe from 1980 to 2018. This overview is important in the sense that it provides the necessary context and explanations for the observed patterns and trends of research collaboration in Zimbabwe.

Chapter 3 (“Aspects of research production and research collaboration in the context of Africa”) discusses the research landscape of Africa. It highlights the publication output of Africa and showcases the sources of data used for African research evaluations. Following this, the chapter discusses the current state and circumstances of research collaboration in Africa according to the scholarly literature. It also discusses the forms of international participation in African science and the different models that explain international participation in African research.

Chapter 4 (“General perspectives on research collaboration”) presents a review of the literature on research collaboration in general. The chapter discusses the different facets of research collaboration (i.e.the levels and types of research collaboration, motivating factors for research collaboration, and factors affecting the collaboration process).

Chapter 5 (“Research design, data sources and methods”) discusses the design and methodology of the study. It provides details of how the bibliometric method and the web-based survey were used to gather and analyse data for the study.

Chapter 6 (“Bibliometric analysis 1: General profile of research production and research collaboration in Zimbabwe”) presents the results of a general bibliometric overview of the trends and patterns of research output and research collaboration in Zimbabwe across four socio-political periods. These periods are the following: Period 1 (1980-1990); Period 2 (1991-1997); Period 3 (1998-2008) and Period 4 (2007-2016). This periodisation was organised around major events, including government decisions and natural disasters that the country has endured over the past five decades.

Chapter 7 (“Bibliometric analysis 2: Research production and research collaboration of Zimbabwean organisations in the different national sectors”) presents a detailed bibliometric analysis of the research production and collaboration trends of Zimbabwean organisations in the four socio-political periods. The chapter profiles the research output and collaboration profiles for the national sectors and organisations in each of six broad fields: agricultural sciences; engineering and technologies; health sciences; humanities; natural sciences; and social sciences.

Chapter 8 (“Bibliometric analysis 3: Participation of ‘international national organisations’ (INOs) in Zimbabwean research”) focuses specifically on the contribution of INOs in Zimbabwe’s research. It determines the extent to which the contribution of INOs’ research in Zimbabwe coincides with international co-authorship. The chapter also presents co-authorship patterns based on a classification framework of authorship types to research in Zimbabwe, where such framework accommodates both INOs and international co-authorship.

Chapter 9 (“Bibliometric analysis 4: Author-level analyses of Zimbabwean researchers”), provides the results of an author-level bibliometric analysis of the Zimbabwean research workforce responsible for articles published between 2009 and 2016. The author-level bibliometric analysis was performed to determine how profiles of research production and research collaboration in Zimbabwe differ when author-level datasets are analysed as compared to when article-level datasets are analysed.

Chapter 10 (“Research collaboration and related activities in Zimbabwe: Results of a survey”) presents findings from an online survey of researchers responsible for Zimbabwe’s article output during the period 2011-2016. The chapter provides a detailed analysis of the reasons for engaging in research collaboration, factors considered by researchers when choosing collaborators, the nature of research collaboration in Zimbabwe, and challenges faced during collaborations. It also provides information about the authorship disputes faced by researchers in Zimbabwe, together with issues related to data ownership and data sharing.

Chapter 11 (“Discussion and conclusions”) discusses the results of the study and summarises the contribution of the study.

CHAPTER 2
Context of research in Zimbabwe

2.1 Introduction

Zimbabwe is located in Southern Africa. The country gained its independence from Britain in 1980. Under British colonial rule, the country earned a reputation in Africa for having strong scientific units and a reputable higher education system (UNESCO, 2014). Most infrastructure for research and research institutions currently present in the country date back to the colonial period. Between 1953 and 1963, Zimbabwe was part of Britain's broader territory referred to as the Federation of Rhodesia and Nyasaland. The federation comprised Southern Rhodesia (modern day Zimbabwe), Northern Rhodesia (modern day Zambia) and Nyasaland (modern day Malawi). During the federation period, Southern Rhodesia (i.e. Zimbabwe) developed one of Africa's strongest higher education systems in terms of both research and education (Hodgkinson & Pasirayi, 2015). In 1957, the colonial government established the University College of Rhodesia (now the University of Zimbabwe), which provided high-quality work force training and a robust system of research facilities aligned to the colony's economic needs (Hodgkinson & Pasirayi, 2015).

A regional survey on the scientific and technical potential of 42 African countries conducted by UNESCO in 1962 showed that Zimbabwe, at that time, had 31 research units (UNESCO, 2014). Of these, 14 units were devoted to agriculture and three to medicine. A further four units were associated with natural museums, six with university departments, and four with a polytechnic institute, geological research centre, meteorological institute and a hydrological research unit, respectively. These units still exist today. Compared with most African countries, Zimbabwe had a developed agricultural research system by the early 1960s. For instance, it engaged about 94 researchers per million economically active agricultural population (i.e. those aged between 15 and 65 years, who were employed in agriculture), compared with an average of 15 for sub-Saharan Africa (ibid.). Research expenditure as a percentage of the gross domestic product (GDP) for agriculture was 1.81%, compared with a continental average of 0.26% (ibid.). The first research institutions within the private sector were established during this era. The colonial government put in place the first operational policy instruments in the world for research based on funding provided by a special tax imposed on the tobacco industry in the country.

Across Africa, the British (in their respective colonies) created research councils that formulated regional research policies and priorities. These councils made recommendations on the allocation of research funds, as well as on projects assigned to institutes (Mouton, 2008). Zimbabwe was no exception. In 1959, the colonial government passed the Scientific Council of Rhodesia through the Research Act (chapter 336). The terms of reference of this council were (Hove & Zinyama, 2012):

- To undertake a review of the areas of research carried out in (the then) Rhodesia, indicating other areas of research which, in the national interest, could be usefully investigated, and suggest suitable lines of research within such areas;
- To provide, when required, advice on scientific priorities to the Treasury and the Ministry of Commerce and Industry; and
- To advise government on matters affecting overall national scientific policy.

In 1967, the colonial government also established the Scientific and Liaison Office (SLO). The main responsibility of this office was to advise on scientific matters. Falling under the Office of the Prime Minister, the SLO was attached to the Scientific Council of Rhodesia (Boshoff, 2014). After independence, the Scientific Council of Rhodesia was transformed – first into the Scientific Council of Zimbabwe and then, in 1986, into the Research Council of Zimbabwe. Today, the Research Council of Zimbabwe is mandated to promote, direct, supervise and coordinate research in the country.

Following the brief historical background of research in Zimbabwe during the colonial period outlined above, Section 2.2 below focuses on the governance of research in the country, including how it is regulated, funded and performed.

2.2 Governance of research in Zimbabwe

The Office of the President and Cabinet (OPC) provides governance for the research system of Zimbabwe. This office is the centre of power in the research system of the country as it oversees the formulation, review, approval as well as implementation of research policy.[3] The governance structure for research includes the Research Council of Zimbabwe (RCZ). The council provides leadership in research for national development. It plays an integral role in policy planning, agenda-setting, budgeting and inter-ministry coordination. The council

[3] Office of the President and Cabinet website: www.theopc.gov.zw, accessed September 2017.

governs research on behalf of the OPC and reports directly to this office. The RCZ also plays intermediary roles in the country's research system, including establishing and maintaining links with professional bodies and centres of excellence to enhance the quality of its role as a facilitator of national and international collaboration.[4] It also links Zimbabwean research to the outside world, and collaborates with other councils in the region.

The RCZ maintains a referral database of all national research activities, namely the National Research Database of Zimbabwe. The purpose of the database is to provide access to and provide information on Zimbabwean research. The operational arms of the RCZ are the following six Committees:[5]

1. The national research prioritization and strategic planning committee which advises the council on national research policy, and recommends the creation of new research councils and research priorities;
2. The research control and coordination committee which considers cases of unethical conduct on behalf of the council, and develops and updates research fund disbursement policies, guidelines and related instruments;
3. The research promotion, publicity and resource mobilisation committee which fosters publication of referred journals, oversees the updating and maintenance of the research council's website, and makes recommendations on grants;
4. The foreign researchers committee which deals with all foreign researchers;
5. The finance committee; and,
6. The human resources committee, which ensures that the organisation runs smoothly and carries out the administrative work of the council.

The RCZ is an established conduit for financial and administrative support for collaborative research among research institutes and councils. According to its website, it identifies broad areas of concern, consults, and brings together relevant experts to define programmes of work and to seek sources of funds. Funding for research is usually sourced from donor organisations, and from the government. The government also ensures that there is funding for research through its budget appropriations process. Funding is then channelled to recipients through the RCZ. However, as will be discussed later in the chapter (Section 2.2),

[4] Research Council of Zimbabwe website: www.rc.ac.zw, accessed June 2019.
[5] Research Council of Zimbabwe website: www.rc.ac.zw, accessed June 2019.

the government of Zimbabwe struggles to meet its target of allocating at least 1% of its GDP to R&D.

Within the governance structure are various ministries involved in research. Examples of these include: the Ministry of Higher and Tertiary Education, Science and Technology Development; the Ministry of Lands, Agriculture and Rural Settlement; and the Ministry of Health and Child Care. These and other ministries have special agencies, such as research councils, with intermediary and research-performing roles. The councils are mandated by various acts of parliament to govern research in the respective ministries (UNESCO, 2014). Examples of Zimbabwe's research councils include the Zimbabwe Council of Higher Education (ZIMCHE), which falls under the Ministry of Higher and Tertiary Education, Science and Technology Development; the Agricultural Research Council of Zimbabwe (ARC), under the Ministry of Lands, Agriculture and Rural Settlement; and the Medical Research Council of Zimbabwe (MRCZ), which is under the Ministry of Health and Child Care (the roles of these councils are discussed in Sections 2.5, 2.6 and 2.7, respectively).

The actors involved in research in Zimbabwe (i.e. R&D performers) are in higher education institutions and universities; government-sponsored research institutes and parastatals; non-profit, non-governmental and community-based organisations; private sector organisations; and even international national organisations (INOs). These actors play a central role in the performance of the system. They undertake research and interact with each other to produce knowledge. Hardeman et al. (2013) state that research interactions might have different properties; namely, interactions concerning competitive pressures among researchers, collaborative efforts, and the transfer of knowledge or the sharing of research facilities. As elsewhere in Africa, the bulk of the research in Zimbabwe is produced by the higher education sector. An outline of the research institutions in the higher education sector in Zimbabwe is provided in Section 2.5. Likewise, an outline of the agricultural and health research institutions is provided in Sections 2.6 and 2.7, respectively. These sectors were selected because Zimbabwe has always had a long, outstanding history of agricultural research, as indicated in the introduction. The country's research output has also always been dominated by health science research (as will be shown in Section 2.7).

Figure 2.1 shows an organogram of the research system of Zimbabwe. It illustrates three dimensions that make up the research system of Zimbabwe; namely, governance, intermediaries, and R&D performers.

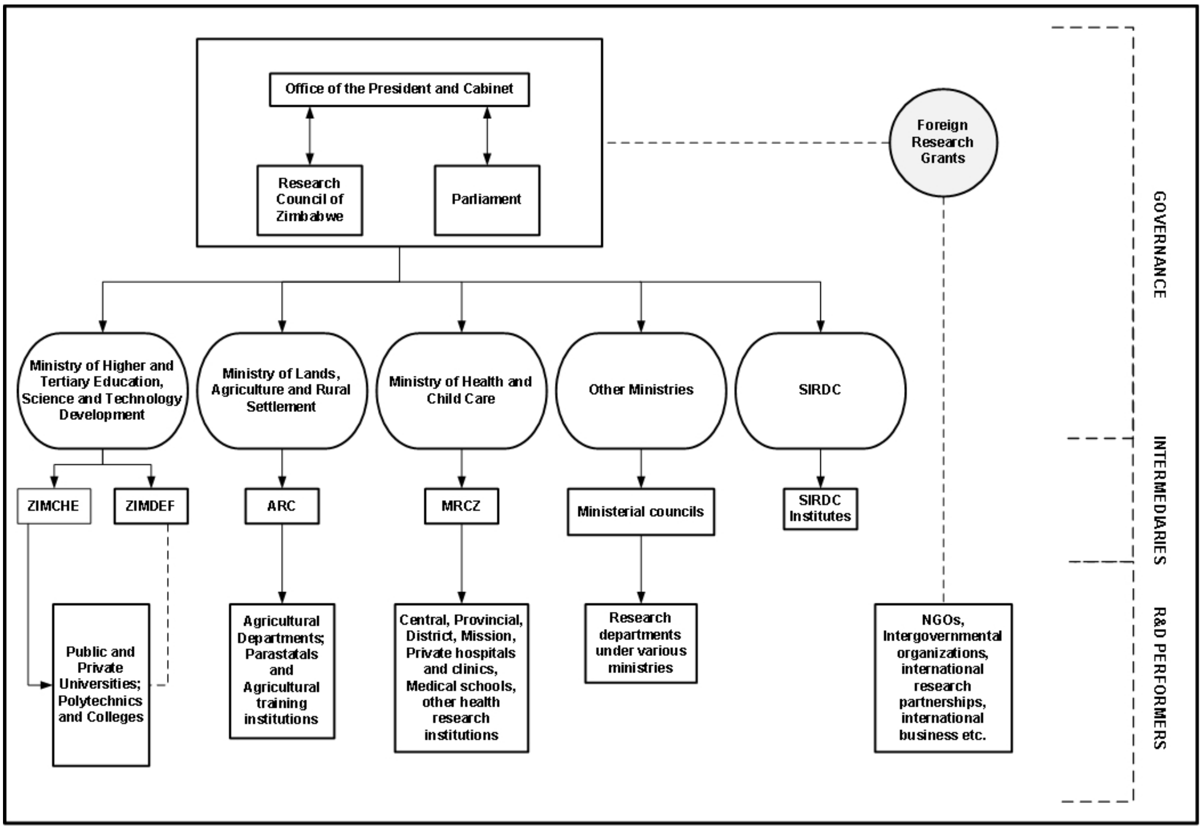


Figure 2.1: An organogram of the research system of Zimbabwe

Source: Author's compilation

Although a structure of a research 'system' is provided above, it is important to note that, as with other developing countries, Zimbabwe's research system does not exhibit typical 'systemic' characteristics. Rather, what is present, as elsewhere in Africa, are disconnected and constantly under-resourced institutions (Mouton, 2008). Since 2000, Zimbabwe has experienced various episodes of socio-political turmoil that have adversely affected all parts of society, including its knowledge production sector. During this period, the country has undergone a massive humanitarian crisis, which has led to many researchers (and potential researchers) migrating to nearby countries, most notably to South Africa (Cross, 2016). Prior to 2000, the country had relied on donor sources for much of its research funding. However, by 2003, most donors had suspended their operations due to political instability (Besada & Moyo, 2008). A discussion of the socio-political landscape of Zimbabwe from 1980 up to 2017 is provided in Section 2.8, which was used to inform a time-based analytical framework applied in the analysis of the bibliometric data.

The sections that follow, 2.2.1 and 2.2.2, provide an overview of the national research priorities of Zimbabwe and the country's science, technology and innovation policy.

2.2.1 National research priorities of Zimbabwe

In 2011, the government approved national research priorities, which the RCZ played a major role in developing. Since Zimbabwe's national research system is characterised by limited funding for research, the national research priorities were identified to channel resources to four areas deemed pivotal for national development. These include:[6]

1. **The social sciences and humanities:** "understanding our role as a nation, what we want, need and where we want to be in future, directing research to deliberately shape out future." The goals are: (i) Strengthening Zimbabwe's social and economic fabric, (ii) Strengthening national policy making processes, (iii) Understanding the region and the world, and (iv) Intellectual property rights in Zimbabwe.
2. **Sustainable environmental and resource management**: improving utilisation of land, water, mineral and energy resources, better understanding of human and environmental systems and the use of new production technologies, as well as aerospace and other sensing technologies. The goals are: (i) Transforming agriculture, (ii) Adding value to Zimbabwe's natural resources, (iii) Valuing water as a critical resource, (iv) Sustainable use of Zimbabwe's ecosystems including forests and biodiversity, (v) Responding to climate change and variability, (vi) Understanding and developing deep earth resources, (vii) Overcoming land degradation, and (viii) Bringing to life Zimbabwe's system of science, technology and innovation.
3. **Promoting and maintaining good health**: promoting good health and wellbeing for all Zimbabweans. The goals are: (i) Increasing access to health facilities, (ii) Preventive health care, (iii) Revitalising Zimbabwe's national health delivery system, and (iv) Fostering a healthy start to life: by countering impacts of genetic, maternal, social, and environmental factors which dispose infants to ill-health and reduce their wellbeing and life potential.
4. **National security of Zimbabwe**: safeguarding Zimbabwe from terrorism, crime invasive diseases and pests, strengthening the understanding of Zimbabwe's place in the region the world. The goals are (i) Protecting Zimbabwe from terrorism and crime, (ii) Transforming defence technologies, (iii) Protecting Zimbabwe from invasive diseases and pests, (iv) Guarding the proper exploitation of the country's resources, and (v) Safeguarding critical infrastructure.

[6] RCZ website: www.rc.ac.zw, accessed June 2019.

Considering the country's research priorities, it is likely that research might be concentrated in only a few fields. The bibliometric analysis of the current study will assist in identifying the relevant fields.

2.2.2 Science, technology, and innovation policies in Zimbabwe

Science, technology and innovation (STI) policies are collective measures taken by governments to encourage the development of scientific and technological research. Such STI policies relate to those policies needed to promote scientific research and to determine and select scientific objectives and goals consistent with national plans or strategies (UNESCO, 2014). Zimbabwe launched its first national Science Technology and Innovation Policy in 2002. From 1980 to 2002, the country did not have an explicit science policy. This does not, however, mean that the country did not recognise the role of science and technology. As early as 1980, the new government of Zimbabwe expressed the need for a new Science and Technology (S&T) Act in its economic policy statement. Similarly, in both the First and Second Five-Year National Development Plans (of 1986-1990 and 1991-1995, respectively) reference was made to the importance of S&T for development (Hove & Zimanya, 2012). The first STI policy was thus released in March 2002, with the RCZ steering the process of policy development. The ultimate objective of this policy was to provide a comprehensive framework within which the country could promote S&T and harness it to economic development. The policy sought to coordinate and direct R&D activities. The overall objective of the policy was to promote national scientific and technological self-reliance by ensuring the following (National Science, Technology, and Innovation Policy of Zimbabwe, 2002):

- Rapid and sustainable industrialisation through R&D that focuses on import substitution;
- Adequate food production and shelter that utilises appropriate and affordable technologies;
- A good health delivery system that uses R&D to explore both modern and traditional medicines;
- Environmentally sound development programmes;
- Provision of sufficient energy resources using science and technology to exploit renewable and non-renewable sources of energy;
- Sustained employment creation; and
- Implementation of the S&T policy objectives.

Less than a decade after the release of the STI policy, a revised policy was launched and released in March 2012. The second STI policy makes reference to a range of sectoral policies including nanotechnology, biotechnology, space sciences, information and communication technologies, indigenous knowledge systems, technologies yet to emerge, and scientific solutions to emergent environmental challenges. The policy makes provisions for establishing a National Nanotechnology Programme. It stresses the government's commitment to allocating at least 1% of GDP to R&D, focusing at least 60% of university education on developing skills in S&T, and ensuring that school pupils devote at least 30% of their time to studying science subjects (Ministry of Science and Technology Development, 2012). The primary goals of the second STI policy are (ibid, p. ix):

- Strengthening capacity development in STI;
- Learning and utilising emergent technologies to accelerate development;
- Accelerating commercialisation of research results;
- Searching for scientific solutions to global environmental challenges;
- Mobilising resources and popularising S&T; and
- Fostering international collaboration in STI.

The presence of these science policies is a clear indication that the government recognises the vital role of research in steering development.

2.3 Public sector R&D expenditure in Zimbabwe

This section discusses the investments made by the Zimbabwean government in R&D, and how the funds are distributed across the R&D performing sectors. In 2012, as other African countries did, Zimbabwe committed to allocate at least 1% of its GDP to R&D (Ministry of Science and Technology Development 2012). Previously, in 2005, the country's gross domestic expenditure on R&D (or GERD) was relatively low, estimated at 0.2% (AU-NEPAD, 2010). However, in 2012, GERD was estimated at 0.76% (UNESCO, 2014). In 2012, the total R&D expenditure was approximately US$142.3 million. Table 2.1 shows the total R&D expenditure by sector in Zimbabwe, with a breakdown by source of funds for the year 2012.

Table 2.1: Total R&D expenditure by sector and by source of funds in million US dollars, 2012

Source of funds	Total R&D expenditure (government and higher education sectors combined)		R&D expenditure in the government sector		R&D expenditure in the higher education sector	
	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage
Direct government	67.8	48%	15.5	64%	52.2	44%
Higher education	53.9	38%	5.7	23%	48.1	41%
General university funds	11.3	8%	-	0%	11.3	10%
Funds from abroad	4.2	3%	0.1	0%	4.0	3%
Private non-profit	3.3	2%	1.1	5%	2.3	2%
Business sector	1.9	1%	1.8	7%	0.1	0%
Total	**142.3**	**100%**	**24.3**	**100%**	**118.0**	**100%**

Source: AU-NEPAD (2014, p. 120)

In 2012, of the total US$142.3 million of R&D expenditure in Zimbabwe, 83% (or US$118.0 million) was in the higher education sector and the remaining 17% (or 24.3 million) in the government sector[7] (see the 'total' row in Table 2.1). The government sector, with a contribution of 48%, is the largest funder of R&D activities. This is followed by the higher education sector with a contribution of 38%. The business sector and foreign sources contribute little to total R&D expenditure in the country, in terms of funding. However, again it needs to be remembered that the R&D survey carried out by UNESCO was limited – it covered only two sectors; it did not include the health sciences and the University of Zimbabwe did not participate in the survey. Still, it is important to note that, historically, as compared to other countries in Sub-Sahara Africa, Zimbabwe received the least funds from abroad. Figure 2.2 shows a distribution of the proportion of international funding for R&D in selected African countries.

[7] It is important to note that the results presented here are based on the only survey on R&D carried out in the country in 2012 by UNESCO. Only two sectors – the higher education sector and the government sector – were covered by the R&D survey.

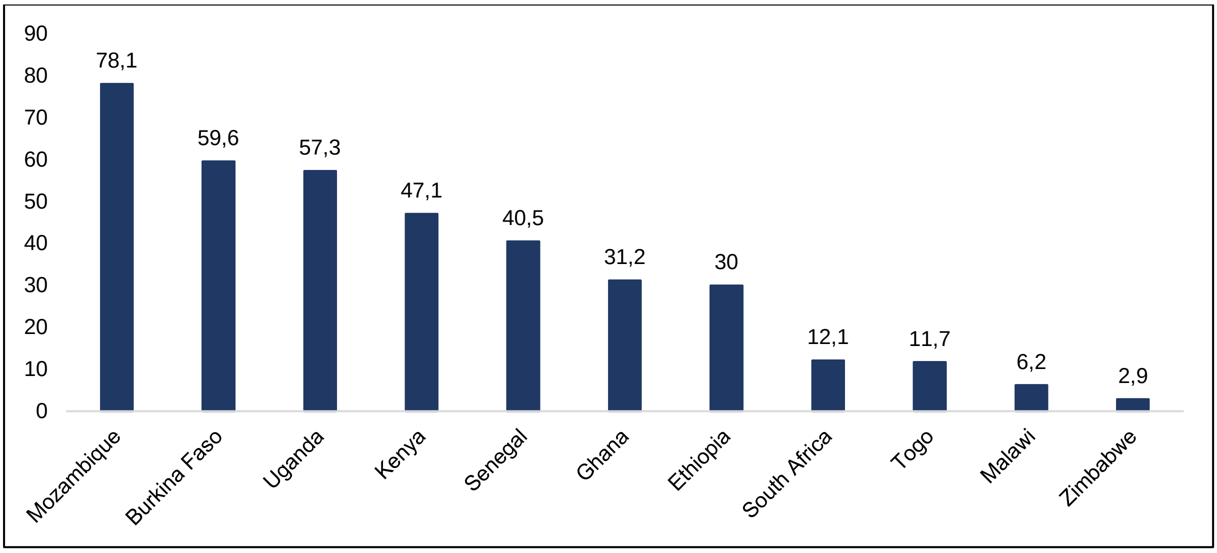


Figure 2.2: Proportion of international funding for R&D by country, 2010 or year available

Source AU-NEPAD (2014, p. 32)

According to Figure 2.2, countries such as Mozambique, Burkina Faso, and Uganda received more than 50% of their R&D funding from foreign sources. However, Zimbabwe recorded a proportion of about 3%, the lowest of them all. This might be because of the strained relations that the country has with Western countries (see Section 2.6).

In terms of scientific field, in 2012, the lagest share of R&D expenditure was concentrated in agricultural sciences (32%; see Table 2.2). It is important to note once again that these results are partial because health sciences were excluded in the UNESCO R&D survey. Natural sciences recorded a share of 21%, followed by engineering and technology (19%). The field of humanities recorded the lowest share (11%).

Table 2.2: Total R&D expenditure by scientific field, 2012

Scientific field	Total R&D expenditure (government and higher education sectors combined)		R&D expenditure in the government sector		R&D expenditure in the higher education sector	
	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage
Agricultural sciences	47.7	32%	10.1	41%	37.6	30%
Natural sciences	29.3	21%	7.9	33%	21.4	18%
Engineering & technology	26.9	19%	4.8	20%	22.1	19%
Social sciences	23.1	16%	1.5	6%	21.6	18%
Humanities	15.3	11%	0.0	0%	15.3	13%
Total	**142.3**	**100%**	**24.3**	**100%**	**118.0**	**100%**

Source: AU-NEPAD (2014, p. 120)

The type of research activities indicates to what extent a country focuses on innovation, knowledge creation, and improvement of the existing technologies. It indicates the priorities of those who fund it and those who carry it out. Generally, universities and research centres undertake basic research while the business sector invests in experimental research aimed at developing products for the market. Table 2.3 shows that, in 2012, the country devoted more than 50% of R&D expenditure to basic research. Basic research is seen as crucial for increasing the stock of knowledge, training R&D personnel and for stimulating collaboration (Salter & Martin, 2001). While the higher education sector devoted 59% of its resources to basic research, the government sector prioritised applied research (51%). This could be the case because governments are mainly interested in research that address societal challenges. According to UNESCO (2015), in a bid to solve pressing development challenges, governments have shifted their focus from basic to relevant or big science (i.e. applied research).

Table 2.3: Total R&D expenditure by type of research activity, 2012

Research activity	Total R&D expenditure (government and higher education sectors combined)		R&D expenditure in the government sector		R&D expenditure in the higher education sector	
	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage	Amount (US$ million)	Percentage
Basic research	77.0	54%	7.6	31%	69.4	59%
Applied research	48.8	34%	12.4	51%	36.4	31%
Experimental development research	16.5	12%	4.3	18%	12.2	10%
Total	**142.3**	**100%**	**24.3**	**100%**	**118.0**	**100%**

Source: AU-NEPAD (2014, p. 120)

2.4 Human resources for public sector R&D in Zimbabwe

The focus in this section shifts to the human resources for public sector R&D in Zimbabwe. Researchers play a significant role in any given research system. They are engaged in the “creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned” (OECD, 2002, p. 92). Information about human resources for the public sector is disaggregated into ‘headcounts’ (HC) or ‘full-time equivalents’ (FTE). Headcount data provides the total number of people who are largely or partially employed in R&D. Headcount data provide useful information about R&D personnel (such as gender, age or nationality). FTE measures the exact time devoted to research activities (ibid.). The sections that follow provide an overview of the R&D personnel in Zimbabwe. Once again, it is important to note that the data presented in this section is largely dependent on the only known country-wide R&D survey conducted by UNESCO in 2012. The biggest limitation with the data is that the private sector and business sectors were not covered. The field of health sciences was also not covered.

In 2012, Zimbabwe had 2 739 headcount researchers (see Table 2.4). Of this total, the majority, 2 511 (92%), were in the higher education sector while the remaining 228 (8%) were in the government sector. Given that the national census reported a population of 13 million in 2012, the total number of public sector researchers per million population amounted to 210 in that year. Women constituted 692 (25.3%) researchers. These figures suggest that women account for at least a quarter of the research workforce in the country.

Table 2.4: R&D personnel (headcount) in Zimbabwe by performance sector, 2012

Sector	Researchers			Technicians			Support staff		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
Government	77	151	228	50	79	129	132	138	270
Higher education	615	1 896	2 511	90	211	301	80	178	258
Total	**692**	**2 047**	**2 739**	**140**	**290**	**430**	**212**	**316**	**528**

Source: UNESCO (2014, p. 52)

Figure 2.3 shows the percentage of women researchers in selected countries. The figure shows that almost half of the research workforce in Namibia, South Africa and Mauritius were women. Zimbabwe, together with Tanzania, Angola and Botswana have more or less the same percentages of women in the research workforce.

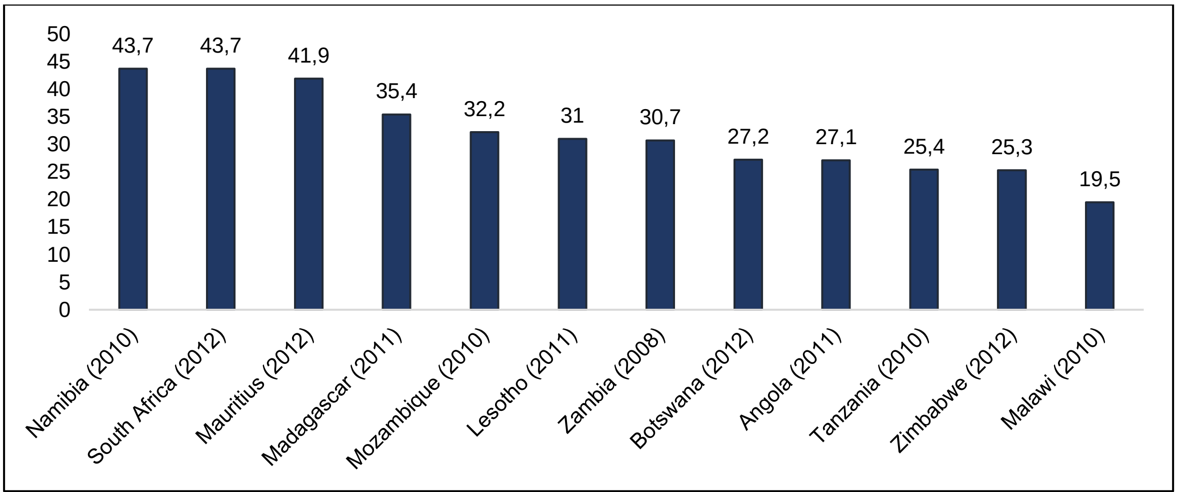


Figure 2.3: Women researchers in selected African countries, 2012 or closest year

Source: UNESCO (2015, p. 543)

R&D personnel (FTE) in Zimbabwe in 2012 are presented in Table 2.5. As can be seen, in 2012, the country had 1 315 FTE researchers. Of this total, 75% were male and 25% female. The higher education sector had the highest percentage of FTE researchers (92%). Measured on the basis of researchers per million, Zimbabwe had a total of 101 FTE researchers per million.

Table 2.5: R&D personnel (FTE) in Zimbabwe by performance sector, 2012

Sector	Researchers			Technicians			Support staff		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
Government	37	72	109	15	27	41	62	86	148
Higher education	295	910	1 205	26	72	98	38	110	148
Total	**332**	**983**	**1 315**	**41**	**99**	**139**	**100**	**196**	**296**

Source: UNESCO (2014, p. 52)

Table 2.6 illustrates that the largest volume of researchers in 2012 was concentrated in the natural and exact sciences. These researchers account for 30% of the total number of headcount researchers and FTE researchers in the country. As already highlighted, health sciences are not represented in the table. However, it is worth mentioning that health plays a central role in the country's research output. Prior to the country's independence in 1980, health sciences accounted for most of the country's publication output (22%). After independence, between 1980 and 2013, health research accounted for the country's largest share of publications with a contribution of 40% (UNESCO, 2014).

Table 2.6: Public sector researchers in Zimbabwe by field of science, 2012

Scientific field	Researchers as headcounts			Researchers as full-time equivalents		
	Female	Male	Total	Female	Male	Total
Agricultural sciences	97	284	381	47	136	183
Arts and humanities	118	306	424	57	147	204
Engineering and technology	85	280	365	41	134	175
Natural and exact sciences	208	615	823	100	295	395
Social sciences	146	461	607	70	221	291
Other	36	98	134	17	47	64
Total	**692**	**2 047**	**2 739**	**332**	**983**	**1 315**

Source: UNESCO (2014, p. 53)

Table 2.7 shows that in 2012 the research workforce in the country was largely dominated by individuals with a master's degree as their highest qualification (2 078 or 75.9%). Individuals with at least a PhD or equivalent accounted for 480 (17.5%) of the total research workforce. The low numbers of researchers with PhDs could be attributed to the continued brain drain, which took place in the country during the 1990s and early to mid-2020s. Mawoyo (2012) reported that when experienced academics left the country, Zimbabwean universities hired underqualified researchers for lecturing posts. However, it is important to note that most academics in Zimbabwean universities are now advancing their studies, as per regulation by the Zimbabwe Council for Higher Education, which requires that every university lecturer should be in the possession of a doctoral degree.[8]

Table 2.7: R&D personnel in Zimbabwe's public sector by qualification, 2012

Qualification	R&D Personnel			Researchers						
				Higher education sector		Government sector		Total		
	Female	Male	Total	Female	Male	Female	Male	Female	Male	Total
ISCED 6	131	358	489	124	346	3	7	127	353	480
ISCED 5A	546	1 619	2 175	457	1 435	68	118	525	1 553	2 078
ISCED 5B	116	230	346	22	71	2	9	24	80	104
ISCED 4 or below	251	436	687	12	44	4	17	16	61	77
Total	**1 044**	**2 643**	**3 697**	**615**	**1 896**	**77**	**151**	**692**	**2 047**	**2 739**

Source: UNESCO (2014, p. 54)

ISCED 6: Doctoral level degrees
ISCED 5A: Master's level/equivalent
ISCED 5B: Tertiary programmes
ISCED 4: Post-secondary education, not tertiary education programmes

2.5 Higher education sector in Zimbabwe

Higher education in Zimbabwe falls under the Ministry of Higher and Tertiary Education, Science and Technology Development. The ministry overseas the promotion of S&T and R&D. According to the website, it "facilitates cooperation in research and development, higher and tertiary education as well as in science and technology, at local, regional and international levels."[9] The ministry has 10 departments. Five of these play fundamental roles in the performance of the performance of the science system. These include:

1. Higher Education Programmes – coordinate and monitor university education;
2. Projects and Technology Transfer – coordinate, promote and facilitate project development and implementation as well as technology transfer across all sectors;
3. Quality Assurance and Standards – regulate Technical and Vocational Education Training (TVET) through the provision of relevant curricula, qualification equivalences, and the accreditation and monitoring of independent TVET institutions;

[8] ZIMCHE website: www.zimche.ac.zw, accessed June 2019.
[9] Ministry of Higher and Tertiary Education, Science and Technology Development website: www.mhtestd.gov.zw, accessed September 2019.

4. Research Development and Innovation – coordinate institutional and scientific research development, innovation and commercialisation; and
5. Tertiary Education Programmes – develop policies in science and technology-led programmes for human capital development in tertiary education institutions.

2.5.1 Zimbabwe council for higher education (ZIMCHE)

The Zimbabwe Council for Higher Education plays intermediary roles in the Ministry of Higher and Tertiary Education, Science and Development. The council was established by an Act of Parliament in 2006. Its main mandate is to promote and coordinate education provided by higher education institutions, and to act as a regulator in determining and maintaining quality standards in higher education.[10] In executing its mandate, the council is guided by policy directives from government through the Parliamentary Portfolio Committee on Higher and Tertiary Education and its Executive Authority, the Minister of Higher and Tertiary Education, Science, and Technology Development. ZIMCHE registers, accredits, audits and engages in quality assurance of higher education institutions in the country. As such, the council develops and improves policies, methods, standards, instruments and tools for use in assuring and enhancing quality. In its 2018-2022 plan, ZIMCHE set out the following four strategic goals and objectives:[11]

1. **Strengthen higher education systems** by (i) building capacity of new institutions on ZIMCHE standards and institutional self-assessment, (ii) carrying out academic, staff and student affairs audits, (iii) assessing foreign qualifications, (iv) accrediting programmes, (v) organising capacity development workshops, and (vi) promoting internationalisation of higher education.
2. **Improving comparability and mobility in higher education** by (i) implementing a Zimbabwe Credit Accumulation and Transfer System, (ii) spearheading the establishment of National Qualifications Framework, (iii) implementing quality assurance standards and guidelines and aligning them to those of regulatory and professional bodies, and (iv) identifying and capacitating peer reviewers.
3. **Improving institutional capacity** by (i) carrying out needs assessments and supporting staff training and development and retention, (ii) seeking accreditation/partnerships with international quality assurance bodies, (iii) promoting and supporting cost reduction measures and viable revenue generation projects and

[10] ZIMCHE website: www.zimche.ac.zw, accessed June 2019.
[11] ZIMCHE website: www.zimche.ac.zw, accessed June 2019.

programmes, and (iv) developing advocacy strategies to raise awareness of the potential and value of ZIMCHE to government, higher and tertiary education institutions and the public.

4. **Improving ICT affordances in higher and tertiary education** by developing a Higher Education Management Information System.

2.5.2 Higher education institutions in Zimbabwe

Most higher education institutions in the country were established after the country's independence. In 1980, the government embarked on a massive education restructuring programme. The new government sought to redress the inherited inequities and imbalances in access to basic needs such as education (Shizha & Kariwo, 2011). The thrust of the government's policy on education was captured by the Transitional National Development Plan, which stressed that education is a basic human right (Chimbodza, 2012). As such, primary schooling was made tuition-free, and this resulted in high admission rates (Shizha & Kariwo, 2011). Naturally, universal primary education resulted in an increased demand for access to higher education. This demand led to the establishment of the National University of Science and Technology in 1991, which became the second state university after the University of Zimbabwe, which had been established in 1953. The continued drive to increase access to higher education resulted in the establishment of more universities in the country.

Currently, the country has a total of 16 universities, of which ten are state-funded and six are privately-owned. Among the state funded universities are: the University of Zimbabwe (est. 1953); National University of Science and Technology (est. 1991); Midlands State University (est. 1998); Great Zimbabwe University (est. 1999); Zimbabwe Open University (est. 1999); Bindura University of Science Education (est. 2000); Chinhoyi University of Technology (est. 2001); Lupane State University (est. 2004); Harare Institute of Technology (est. 2005); and Gwanda State University (est. 2014). Private universities include Solusi University (est. 1894); Africa University (est. 1992); Catholic University (est. 1998); Women's University in Africa (est. 2002); Reformed Church University (est. 2012); and Zimbabwe Ezekiel Guti University (est. 2012). Solusi University and Africa University were the first two privately-owned universities in the country. Most private higher education in Zimbabwe is funded by religious organisations. The Africa University is funded by the United Methodist church while the Solusi University is funded by the Seventh Day Adventist Church. Other religious organisations that fund universities include the Roman Catholic Church, which is associated with the Catholic University; the Zimbabwe Assemblies of God Africa (ZAOGA) associated with Zimbabwe

Ezekiel Guti University; and the Dutch Reformed Church, which funds the Reformed Church University. Higher education in the country is also provided through technical colleges, polytechnic colleges and teacher training colleges.

All the state and private universities in the country produce the bulk of research, given that the higher education sector employs 92% of the country's researchers (UNESCO, 2014. Funding for research in higher education institutions comes from foreign grants, consultancies and the government. Universities also have internal funding systems from their research boards. For example, academics at the National University of Science and Technology can apply, through the university's Research and Innovation Office, for research grants (maximum US $5 000), small block allocations for research (maximum US $210), and travel grants (maximum US $2 500) (NUST, 2011).

2.5.3 Enrolment of students in higher and tertiary education in Zimbabwe, 2006-2012

The total number of students enrolled in the country's higher education institutions has been increasing steadily. The hyperinflation and economic crisis experienced by the country in 2008 resulted in a decrease of 18.7% in total enrolment in 2009 (UNESCO, 2014). However, this trend has since been reversed, with enrolment being 11.8% higher in 2012 than in 2006 (ibid.). The steady increase in the total enrolments is clearly shown in Table 2.8.

Table 2.8: Enrolment in selected higher and tertiary education institutions in Zimbabwe, 2006-2012

Institution	Year						
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Africa University	1 155	1 560	1 391	666	1 566	1 384	1 701
Agricultural colleges	1 622	2 144	1 245	1 717	927	816	958
Bindura University of Science Education	1 056	1 654	2 116	1 923	2 116	4 394	4 732
Catholic University	313	313	332	315	385	387	437
Chinhoyi University of Technology	2 286	3 287	2 586	2 381	4 533	4 533	5 124
Great Zimbabwe University	2 394	2 655	3 036	2 690	2 671	4 201	4 481
Harare Institute of Technology*	-	141	343	273	622	1 245	1 446
Lupane State University*	-	-	78	205	521	862	1 206
Midlands State University	9 904	10 422	10 887	3 868	10 648	10 258	14 915
National University of Science and Technology	3 594	3 594	5 651	5 099	4 057	7 098	3 087
Solusi University	1 877	1 875	1 753	1 233	1 952	338	672
Teachers training colleges	18 297	17 665	15 593	10 812	11 575	12 825	18 809
Technical colleges	14 361	13 040	12 855	11 234	12 220	16 859	17 432
University of Zimbabwe	12 050	11 484	11 725	12 271	7 636	8 310	11 975
Vocational training colleges	988	915	728	765	1 016	2 295	1 807
Women's university in Africa	473	613	1 581	1 203	1 537	1 517	1 472
Zimbabwe open university	18 307	17 246	17 816	16 286	15 303	8 568	8 895
Total	**88 677**	**88 608**	**89 716**	**72 941**	**79 467**	**85 890**	**99 149**

Source: UNESCO (2014, p. 45)

*The Harare Institute of Technology had its first intake of students in 2007, Lupane State University in 2008. The Reformed Church University was only established in 2012 and does not appear in the table.

In 2019, the country's oldest university, the University of Zimbabwe, produced a total of 22 PhDs in several faculties. The majority, five (22%), were from health sciences and law respectively. The university also had a total of 747 master's graduates and the majority, 228 (31%), were from the field of social sciences. Although the National University of Science and Technology had relatively fewer PhD graduates, it produced a total of 678 master's graduates of which the majority were from the faculty of commerce. Table 2.9 shows the distribution of the master's and PhD degrees awarded to students at the two respective universities in 2019.

Table 2.9: Number of master's degrees and medical doctors/PhDs from the University of Zimbabwe and the National University of Science and Technology, 2019

Faculty	University of Zimbabwe		National University of Science and Technology	
	Masters	MD/PhD	Masters	MD/PhD
Agriculture	31	2	-	-
Arts	77	4	-	-
College of health sciences	73	5	7	-
Commerce	167	1	391	4
Education	54	3	-	-
Engineering	58		22	-
Law	59	5	-	-
Social sciences	228	2	-	-
Veterinary sciences	4	-	-	-
Applied science	-	-	110	1
Built environment	-	-	46	-
Communication and information science	-	-	49	-
Science and technology education	-	-	53	1
Total	**747**	**22**	**678**	**6**

Sources: University of Zimbabwe (2019); NUST (2019)

2.6 Agricultural research in Zimbabwe

The economy of Zimbabwe is largely driven by agriculture. Agriculture provides livelihoods to 80% of the country's population. The agricultural sector provides 40% of the country's export earnings and contributes 60% of raw materials to agro-industries. Agricultural-related employment supports a third of the formal labour force. Government allocates 41% of its expenditure on R&D to agricultural sciences, a percentage that is four times higher than the African Union agricultural budget allocation.[12]

Prior to independence, the agricultural sciences accounted for about 18% of the country's publication output. Between 1980 and 2013, they accounted for 20% (the second largest contribution after the health sciences) (UNESCO, 2014). Fourteen percent of a headcount of 2 739 researchers in the country were in agricultural sciences (ibid.). As mentioned earlier in section 2.3, the results provided by UNESCO are partial as some sectors were not surveyed. The Agricultural Science and Technology Indicators (ASTI) initiative of the International Food Policy Research Institute provides more comprehensive information about agricultural R&D in Zimbabwe. Figure 2.4 shows the total number of FTE researchers in agriculture for the period 2003-2016, as reported by ASTI (2020). As can be seen in the figure, the number of FTE

[12] The African Union Commission, through the Maputo Declaration of 2003, encouraged member states to allocate at least 10% of their national budget towards agriculture.

researchers in agriculture steadily increased from 144 in 2003 to 242 in 2016. The government sector employs more FTE researchers than any other sector in the country. The share of FTE researchers employed by the higher education sector increased dramaticlly, especially from 2011 onwards (i.e from 50 in 2011 to 93 in 2016).

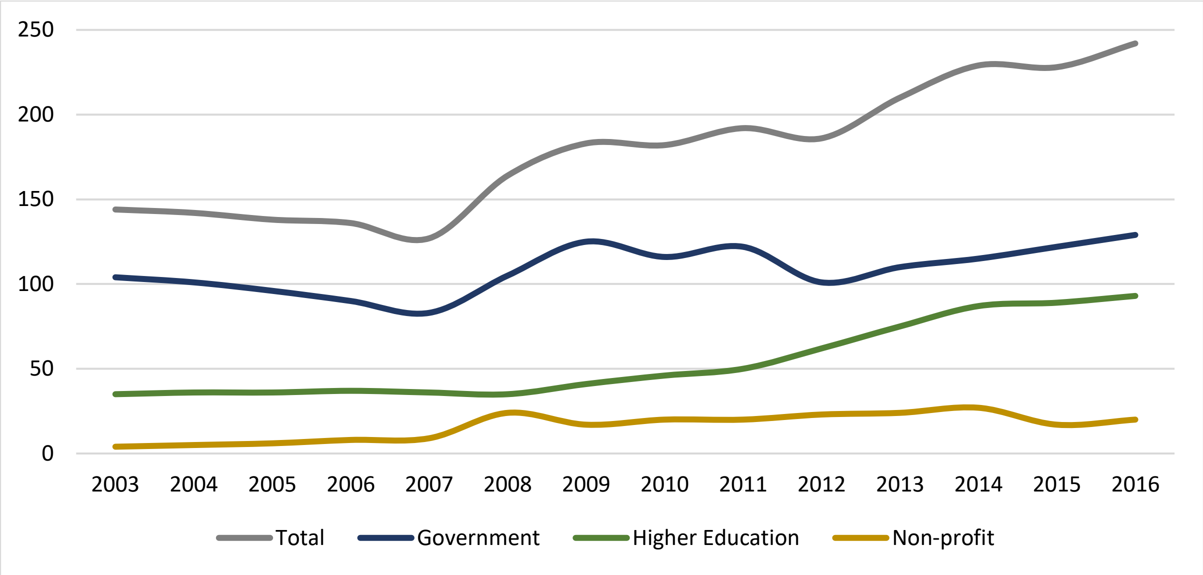


Figure 2.4 Number of agricultural researchers (FTE) in Zimbabwe, by sector, 2003 to 2016
Source: ASTI (2020)

Most of the agricultural research in Zimbabwe falls under the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement. Within the ministry is the Agricultural Research Council. The council's main mandate is to promote and coordinate agricultural research in the country. It also facilitates the implementation of developmental activities emanating from agricultural research output.[13] The ministry hosts several departments, parastatals and colleges involved in agricultural research. These include:

- Agricultural departments: AGRITEX; the Department of Research and Specialist services (DRSS); Economics and Markets; Livestock and Veterinary; and Mechanisation and irrigation.
- Agricultural parastatals: Agribank; Agricultural and Rural Development Authority (ARDA); Pig Industry Board (PIB); Tobacco Research Board (TRB); Agriculture Marketing Authority (AMA); Grain Marketing Board (GMB); Tobacco Marketing Board (TMB); and Cold Storage company (CSC).

[13] Agriculture Research Council of Zimbabwe website: www.moa.gov.zw, accessed October 2019.

- Agricultural training colleges: there are 14 agricultural colleges in eight provinces (see Table 2.10).

Table 2.10: Agricultural training colleges in Zimbabwe, by province

Province	Agricultural training college
Mashonaland West	• Gwebi agricultural college • Chibero agricultural college • Mashayamombe agricultural college
Mashonaland Central	• Mazowe veterinary college • Chaminuka agricultural college
Mashonaland East	• Kushinga Phikelela agricultural college
Masvingo	• Mushagashe agricultural college • Rupangwane agricultural college
Matabeleland South	• Esigodini agricultural college
Matabeleland North	• Inyathi agricultural college
Manicaland	• Magamba agricultural college
Midlands	• Mlezu college • Rio Tinto college • Kaguvi agricultural college

Source: Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement website: www.moa.gov.zw, accessed October 2019.

2.6.1 Zimbabwe comprehensive agricultural policy framework

The Zimbabwean Comprehensive Agricultural Policy Framework highlights the country's vision, goals, objectives and detailed policy statements and strategies for the development of the agricultural sector, for the period 2012-2032. The vision of the agricultural sector, as stated in the framework, is establishing "a prosperous, diverse and competitive agriculture sector, ensuring food and nutrition security significantly contributing to national development" (Echanove, 2017, p. 2). In the framework, the role of agricultural research in meeting the vision of the sector is emphasised. Three research-oriented objectives set in the framework are (Ministry of Agriculture, Mechanisation, and Irrigation Development, 2012):

1. Working towards an adequately resourced agricultural research system by
    - Building institutional and human resource capacities to strengthen research and service delivery;
    - Providing a budgetary allocation aimed at improving capital and recurrent expenditure for increased research outputs;
    - Developing mechanism for attracting, capacitating and retaining staff for sustained research and service delivery;
    - Promoting agri-business participation and support for agricultural research; and

   - Promoting and strengthening of partnerships of national agricultural research institutions.
2. Increasing the number of publications on research-based information and technologies by
   - Facilitating the establishment of national agricultural journals;
   - Promoting collaborative research, regular national agricultural research workshops and symposia to increase the sharing of research information with the agricultural industry, universities, and other stakeholders; and
   - Providing financial resources that support the effective packaging of information and technologies in manuals for use by farmers and to enable researchers to pay for scientific publication in regional and international peer reviewed journals.
3. Setting up research priorities with the involvement of clients by
   - Establishing and funding a coordination mechanism between research and extension to enhance participatory prioritisation of research programmes and sharing of research information with the agricultural industry.

2.6.2 Agricultural research organisations in Zimbabwe

The most prominent local agricultural research organisation outside the public universities is the Department of Research and Specialist Services (DRSS). The DRSS has been in operation since 1948 (UNESCO, 2014) and falls under the Ministry of Lands, Agriculture and Rural Settlement. Flaherty et al. (2011) reported that the DRSS accounted for up to two-thirds of national agricultural research investments and human resource capacity in the 1980s and early 1990s. It had more than 150 FTEs in the early 1990s. However, due to the country's political and economic constraints, by 2008 it employed less than a quarter of the nation's public research staff (i.e. 35 FTE researchers). The research produced by DRSS is largely focused on practical local issues facing small- and medium-scale farmers in Zimbabwe today. DRSS has three divisions focusing on crop research, animal research and research services, respectively:

1. The Crop Research Division consists of six research institutes:
   - Coffee Research Station
   - Cotton Research Station
   - Horticulture Research Institute
   - Agronomy Research Institute

   - Crop breeding Research Institute
   - Chiredzi Research Station
2. The Animal Research Division consists of four research stations:
   - Matopo Research Station
   - Henderson Research Station
   - Grasslands Research Institute
   - Makoholi Research Institute
3. In addition to providing technical services to the other two divisions, the Research Services Division oversees seven subunits, including two institutes: The Plant Protection Research Institute and the Chemistry and Soil Research.

The Tobacco Research Board, the Department of Veterinary and Laboratory Service (DVLS), the Forestry Research and the Training Division, and the Institute of Agricultural Engineering (IAE) also play central roles in agricultural research. Flaherty et al. (2011) report that, taken together, these four institutions accounted for 39% of total public agricultural research staff in 2008. Although the majority of public universities in the country contribute to agricultural research output, it is important to note, as observed by Donovan (1995, p. 262), that already in the early 1990s, both the volume and practical value of agricultural research at the universities were reduced due to “the higher priority for teaching, dependence on short-term contract academic staff and the lack of direct extension links”.

Non-governmental organisations (NGOs) and some entities in the private sector also contribute to the country’s agricultural research. In the private sector, SeedCo, which is reported to have had 10 FTE researchers in 2008, is one of the country’s longest standing private sector organisations conducting agricultural research in the country (Flaherty et al., 2011). The Agricultural Research Trust (ART) established in 1982, African Institute for Agrarian Studies (AIAS) established in 2003, and the Ruzivo Trust established in 2004 are a few examples of NGOs involved in agricultural research in the country. According to Flaherty et al. (2011), together these three NGOs employed 17 FTEs in 2008.

Despite the strained relations between Zimbabwe and the international community (see Section 2.6), a number of INOs continued to operate in the country. Prime among these are the Consultative Group on International Agricultural Research (CGIAR); (e.g. the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) with its headquarters based in India; the International Institute of Tropical Agriculture (IITA) with its headquarters in Nigeria;

the International Maize and Wheat Improvement Center (CIMMYT) based in Mexico; and the International Center for Tropical Agriculture (CIAT) based in Colombia.

Zimbabwe is a member of the Southern African Development Community (SADC). It participates in the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), the Soil Fertility Consortium for Southern Africa (SOFECSA), and the New Seed Initiative for Maize in Southern Africa (NSIMA) (Mutisi, 2009). It also hosts the Africa Centre for Fertilizer Development (ACFD), established by the African Union.

2.7 Health research in Zimbabwe

Health research has always played a pivotal role in Zimbabwe's research landscape. According to UNESCO (2014), health research in Zimbabwe accounted for the largest share of the country's total publication output, prior to and after independence, between 1980 and 2013 (i.e. 20% and 40%, respectively). Currently, health research falls under the Ministry of Health and Child Care. The Medical Research Council of Zimbabwe, (MRCZ) regulates all health research in the country. It gives independent guidance, advice and decisions on biomedical research conducted within the country by all researchers.[14] Funding for health research is low and has remained limited at 2-3% of the Ministry of Health and Child Care expenditure (Ministry of Health and Child Care, 2016). That said, various agencies conduct research to support programmes in the ministry and associated sectors.

2.7.1 The national health strategy for Zimbabwe, 2016-2020

The vision of the Zimbabwe Ministry of Health and Child Care is "to have the highest possible level of health quality of life for all its citizen" (ibid., p. x). To achieve this vision, the *National Health Strategy for Zimbabwe 2016-2020 – Equity and Quality of Health* was developed. It lays out the health agenda for 2016-2020 taking into account the broader policy context that is defined by the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim-Asset)[15] and the sustainable development goals (SDGs).

Zimbabwe's national health strategy has three main goals. Goal 3 seeks to improve the enabling environment for service delivery. One of the key result areas in this goal is R&D. An

[14] Medical Research Council of Zimbabwe website: www.mrcz.org.zw, accessed September 2019.
[15] Zim-Asset is a blueprint for the country's development path. It was set to run from 2013-2018. It provided the basis and context for all sectoral strategies and programs towards the achievement of its vision, *Towards an empowered society and growing economy* (Zim-Asset, 2013).

objective set to achieve this result area is to improve the uptake of scientific research evidence for decision making and policy development by 70%. Under this objective are the following five targets:

1. Developing a national health research policy and establishing an essential national health research agenda for the country by
    - Developing a national health research policy; and
    - Conducting consultative processes for reviewing the national health research agenda.
2. Developing human capacity for health research development by
    - Building capacity for health research and development (human, material and financial capacity) at national, provincial, district and community levels.
3. Promoting the translation of research into policy, practice and product by
    - Establishing a technical working group for health research and development that will push the health research agenda and the use of health research for evidence-based decision making and policy development; and
    - Convening results sharing fora or mechanisms at various levels.
4. Conducting research on priority areas. This is to be achieved by
    - Ensuring research approval system informed by national health priorities;
    - Encouraging collaborative projects with other institutions and investigators including practitioners;
    - Promoting research excellence; and
    - Conducting a hepatitis survey that will inform intervention strategies.
5. Strengthening the research framework for traditional medicine. This is to be achieved by
    - Conducting research on traditional medicine to inform practices; and
    - Promoting evidence-based practices.

The national health strategy presented above shows the commitment by the Ministry of Health and Child Care to improving health research and research uptake. The strategic plan emphasises the role of research and development in the delivery of quality health services.

2.7.2 Health research organisations in Zimbabwe

The bulk of health research in the country is produced by two medical schools: namely, those of the University of Zimbabwe and the National University of Science and Technology. The

College of Health Sciences at the University of Zimbabwe was established in 1963, under the auspices of the University of Birmingham in the United Kingdom. It conducts the bulk of health research in the country. It offers several health degree programmes (i.e. in medicine, dentistry, rehabilitation, pharmacy, etc.). The college hosts a library that serves as the country's national focal point for health information.

Outside the university sector, health research is also produced by local organisations such as the Biomedical Research and Training Institute, a Zimbabwean NGO, and the National Institute of Health Research (NIHR), formerly known as the Blair Research institute. The institute was established in 1939. To date, the NIHR is an important agency that conducts national health research. UNESCO (2014) reported that with a contribution of 3.6%, the NIHR accounted for the second largest share (after the University of Zimbabwe) of the country's publication output between 1980 and 1990. It accounted for 3.2% (again second only to the University of Zimbabwe) of the country's total publication output between 1991 and 2001. The Biomedical Research and Training Institute acquired affiliate status with the University of Zimbabwe Institute of Continuing Heath Education in the College of Health Sciences. It is a recognised centre for international collaborative research and training with a focus on HIV/AIDS, tuberculosis and malaria. Between 2002 and 2012, the institute accounted for 4.72% of the country's publication output (i.e. third after the University of Zimbabwe and the National University of Science and Technology) (ibid.). In 2013, it produced 5.38% of the country's publication output, again third following the University of Zimbabwe and the Bindura University of Science Education (ibid.).

As with the agricultural sciences, researchers in the health sciences have been able to withstand some of the country's socio-political challenges due to the availability of international funding and partnerships. For example, the University of Zimbabwe Clinical Research Center (UZ-CRC), which is the country's highest funded centre, has longstanding partnerships with the University of California, San Francisco. The centre also benefitted from international donors such as the Bill and Melinda Gates Foundation, the WHO, and the Wellcome Trust (Hodgkinson & Pasirayi, 2015).

2.8 Socio-political overview of Zimbabwe, 1980 to 2017

Following independence in 1980, Zimbabwe underwent a series of events that negatively affected all societal sectors, including human capital and R&D. This section therefore discusses Zimbabwe's socio-political landscape from 1980 onwards. The relevant events are grouped into four periods and are discussed as such. Figure 2.4 illustrates these broad, significant socio-political periods. This periodisation has been organised around major events, including government decisions and natural disasters that the country has endured over the past five decades and which have had a significant impact on the socio-political landscape. The first period, 1980-1990 represents the first ten years after the country's independence. The second period 1991-1997, marks the period when the Zimbabwean government adopted the Economic Structural adjustment program (ESAP), the years soon after up to when the country succumbed to natural disasters and the global recession. The third demarcation 1998-2008, represents the period when the Zimbabwean government engaged in land reform programmes which dismally affected the agricultural economic base of the country; it's the period when the country had high levels of inflation, and when it was served with economic sanctions and faced international isolation. The last period 2009-2016, represents the point when Zimbabwe adopted a coalition government and had slow economic growth. These periods are presented in detail in the sections that follow.

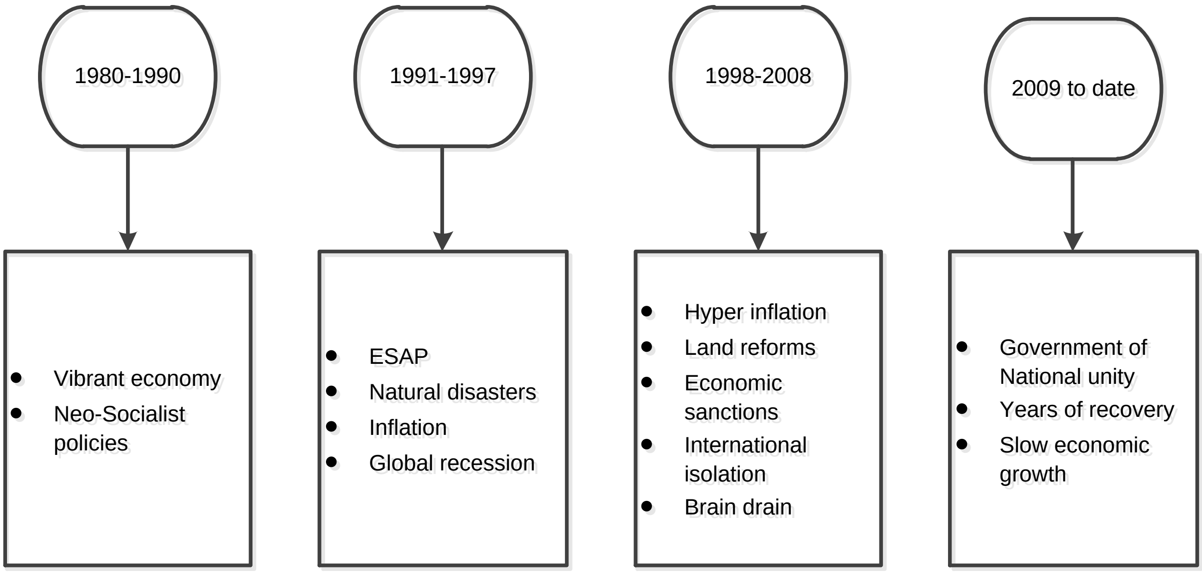


Figure 2.5: Socio-political history of Zimbabwe, 1980–2016, presented as four periods

Period 1 (1980-1990): Independence, vibrant economy and neo-socialist policies

In the early years after independence, Zimbabwe had a vibrant economy (UNESCO, 2014). The production capacity of most sectors of the economy responded positively to the advent of independence where war expenses were channelled towards economic growth in a time of peace. A solid economic growth of approximately 2.9%, well above the southern African regional average of 1.7%, was recorded (UNCTAD, 2007). However, this growth only lasted a few years as the government soon engaged in experimental neo-socialist policies (i.e. free education, minimum wages, free low cost of housing, and free health). These policies strained an economy that had been structured to provide such services to the minority white community. As a result, government expenditure outstripped fiscal revenue, and key sectors such as agriculture, mining and tourism (in their order of importance to the national economy) began to suffer. By the end of the 1980s, the economy was showing signs of stress owing to misappropriated government expenditure (Chimboza, 2012; Zvobgo, 2003).

Period 2 (1991-1997): Adoption of Economic Structural Adjustment Programme (ESAP), natural disasters and global recession

During this period, the government of Zimbabwe adopted the Economic Structural Adjustment Programme (ESAP). ESAP had adverse effects on the country's higher education sector. It prioritised basic education at the expense of higher education. The argument was that social returns on investment in basic education were far greater than those in higher education (Mouton, 2018; Patrinos & Psacharopoulos, 2002). Universities were thrown into financial crisis as insufficient government funding led to low salaries for university teaching staff and low pay-outs for students. Faced with poor salaries and poor working conditions, academics abandoned basic research and instead turned to "better paying worlds of consultancies" (Mlambo, 2005, p. 109). Some academics left the country and those who remained used their university jobs to do their private consultancy work. Not only did ESAP affect tertiary education, it also had a negative impact on the economy. Although it was hoped that the programme would ensure economic growth, the opposite was achieved. Economic growth was stifled, employment contracted, many firms closed, and social services deteriorated. Inflation in the country rose and real wages decreased. Wages and salaries as a percentage of GDP plummeted from 57% in the 1980s to 45% by 1995 (Chimboza, 2012). Besides the effects of ESAP, natural disasters in 1991 and 1992, a global recession in 1991/1992, and political issues all affected the country's workforce. As a result, thousands of skilled personnel left the country.

Period 3 (1998-2008): Land reforms, sanctions, international isolation and hyperinflation

Between 1998 and 2008, Zimbabwe experienced the worst socio-economic and political travails ever recorded in the country's history. The government engaged in land reform programmes that negatively affected commercial farming. In 2000, war veterans invaded white-owned commercial farms. Land grabbing crippled Zimbabwe's commercial industry, once dominated by 4 500 mainly white farmers and which, in the past, had constituted some 20% of the country's GDP and 40% of its export earnings. By 2006, agriculture's share of GDP had dropped to 15%. Most land grabbers did not have the experience and infrastructure to pursue commercial farming. As a result, during this period agricultural output dropped by 51% (UNESCO, 2015). The land reforms marked a turning point in the country's economy as the commercial agriculture sector, the country's major export sector, was effectively destroyed.

Not only was the agricultural base of the economy destroyed, at least in the short to medium term, it also set Zimbabwe on what has become a protracted international conflict with the Western countries. Mlambo (2005) remarks that the controversial land reforms turned Zimbabwe into a pariah state, boycotted by the international community and targeted with economic sanctions. The International Monetary Fund (IMF) and the World Bank ceased their funding obligations. In 2000, the World Bank announced that it would stop extending loans to the country (Beseda & Moyo, 2008). Foreign direct investment shrank as there was a drop in investor confidence. By 2003, most donors had suspended their operations in Zimbabwe. Also at that time, expenditure on R&D was recorded as one of the lowest in the world. In May 2008, the official annual inflation rate reached 1 000 000% (ibid.), and peaked to 231 000 000% in July that same year (UNESCO, 2015). This period saw a mass exodus of skilled professional and intellectuals. For example, in 2002, the University of Zimbabwe was left with a staff complement of only 500 lecturers out of a regulated staff complement of 1 200 (Mlambo, 2005). When experienced academics left the country, institutions hired underqualified researchers for lecturing posts. This new staff profile had the consequence of hampering and limiting institutional research output as junior lecturers did not have adequate research skills (Mawoyo, 2012). In addition to the staff complement leaving the country, this period also experienced a surge of higher education students leaving the country to study abroad. Table 2.11 shows the numbers of Zimbabwean students enrolled in South African universities during the period 2000-2008. The table shows a significant increase over the years, and that an average of 847 master's student and 234 doctoral students were enrolled per year.

Table 2.11: Total number of Zimbabwean students enrolled in South African universities, 2000-2008

Year	Total enrolments	All undergraduates	Postgraduates		
			Honours	Masters	Doctoral
2000	6 530	5 137	457	561	71
2001	7 273	5 711	498	555	92
2002	9 221	7 465	458	663	160
2003	10 632	8 442	495	1 092	181
2004	9 057	6 790	584	930	225
2005	9 748	7 432	659	863	254
2006	9 883	7 489	703	824	305
2007	14 995	11 636	922	949	347
2008	18 154	14 073	1 014	1 185	468
Average	**10 610**	**8 242**	**643**	**847**	**234**

Source: HEMIS Data, CREST

Table 2.12 shows the total number of Zimbabwean master's and doctoral students enrolled in South Africa, between 2000 and 2008, in six broad fields. The table shows that the fields of social sciences and humanities had the highest enrolment figures. The table shows that during the years under review, an average of 87 PhD Zimbabwean master's students per year were enrolled in the field of social sciences, and an average of 96 PhD students per year were enrolled in the humanities.

Table 2.12: Total number of master's and doctoral Zimbabwean students enrolled in South African universities, by fields, 2000-2008

Year	SS		NS		HU		HS		EN		AS	
	M	D	M	D	M	D	M	D	M	D	M	D
2000	403	19	19	19	43	11	54	5	33	7	8	7
2001	385	32	28	17	43	16	50	6	37	12	11	7
2002	428	65	47	23	70	32	44	6	59	24	15	10
2003	821	71	53	33	80	37	57	3	68	26	13	11
2004	648	85	63	46	93	45	53	4	58	30	15	15
2005	530	89	63	52	105	47	75	22	67	25	23	19
2006	442	111	89	83	114	43	71	17	69	29	38	22
2007	458	122	101	97	162	54	84	20	97	29	47	25
2008	562	186	141	125	154	61	106	25	137	32	85	39
Average	**520**	**87**	**67**	**55**	**96**	**38**	**66**	**12**	**69**	**24**	**28**	**17**

Source: HEMIS Data CREST
M=masters D=doctoral
SS=social sciences; NS=natural sciences; HU=humanities; HS=health sciences; EN=engineering, architecture and built environment; AS=agricultural sciences.

Period 4 (2009-2017): Government of National Unity, years of recovery and slow economic growth

Hyperinflation was brought into check in 2009 when the Government of National Unity (GNU) was put in power. This government consisted of the country's ruling political party and the main opposition party. Between 2009 and 2013, the new government embarked on economic policies that created a more stable macro-economic environment. Once stabilised, the economy grew by 6% in 2009 and slightly dropped to 4.5% in 2013. Foreign direct investment as a percentage of GDP was 3.0 in 2013. Table 2.13 shows the economic landscape of Zimbabwe and how it compared to the rest of Southern Africa during this period.

Table 2.13: Economic landscape of countries in Southern Africa, 2009 and 2013

Country	GDP per capita in PPP$ millions (2011 constant prices)			GDP growth		Overseas development assistance		FDI inflow, 2013 (% of GDP)	Number of patents, 2008-2013
	2009	2013	5-year change (%)	2009 (%)	2013 (%)	2009 (%)	2013 (%)		
Angola	7 039	7 488	6.4	2.4	6.8	2.1	1.6	-5.7	7
Botswana	12 404	15 247	22.9	-7.8	5.8	7.8	2.2	1.3	0
Congo, Dem. Rep.	657	783	19.1	2.9	8.5	87.2	38.3	5.2	0
Lesotho	2 101	2 494	18.7	3.4	5.5	26.5	33.0	1.9	0
Madagascar	1 426	1 369	-4.0	-4.0	2.4	14.9	30.0	7.9	0
Malawi	713	755	5.9	9.0	5.0	64.3	--	3.2	0
Mauritius	15 018	17 146	14.2	3.0	3.2	6.7	5.9	2.2	0
Mozambique	893	1 070	19.7	6.5	7.4	--	85.0	42.8	0
Namibia	8 089	9 276	14.7	0.3	5.1	13.1	7.8	6.9	2
Seychelles	19 646	23 799	21.1	-1.1	5.3	9.8	5.2	12.3	2
South Africa	11 903	12 454	4.6	-1.5	2.2	1.7	1.8	2.2	663
Swaziland	6 498	6 471	-0.4	1.3	2.8	17.2	31.9	0.6	6
Tanzania	2 061	2 365	14.7	5.4	7.3	35.6	26.2	4.3	4
Zambia	3 224	3 800	17.8	9.2	6.7	-	17.4	6.8	0
Zimbabwe	1 352	1 773	31.2	6.0	4.5	76.7	46.3	3.0	4

Source: UNESCO (2015, p. 537)

Compared to other countries in Southern Africa, Zimbabwe had a relatively low GDP per capita between 2009 and 2013. However, its GDP growth was quite positive. Although the GDP dropped from 6.0 in 2009 to 4.5 in 2013, it still showed a positive outlook. As in most countries in the region, with the exception of Lesotho, Madagascar and Swaziland, overseas development assistance declined.

The production structure of Zimbabwe, like most SADC economies, is resource-based with a relatively small manufacturing sector (Table 2.14). Services such as banking institutions, insurance and telecommunications have been driving African economies. Previously, the Zimbabwean economy was driven by agriculture. However, as shown in Table 2.4 in 2012 agriculture constituted 12% of the country's GDP, the least in the listed economic sectors. The sharp drop of GDP in the agriculture sector could be attributed to the country's land reform programmes. As compared to other countries in the region, results in the table illustrate a relatively positive outlook in terms of the country's GDP by economic sector.

Table 2.14: Zimbabwe's GDP disaggregated by economic sector, as compared to other countries in the SADC region, 2012

Country	Economic sector			
	Agriculture	Services	Industry	Manufacturing as a subset of industry
Angola	10.1	32.1	57.8	7.2
Botswana	2.2	60.5	36.9	5.7
Congo, Dem. Rep.	20.8	41.0	38.2	16.6
Lesotho	8.3	59.9	31.8	11.7
Madagascar	26.4	57.5	16.1	-
Malawi	27.0	54.2	18.8	10.7
Mauritius	3.2	72.5	24.3	17.0
Mozambique	29.0	50.2	20.8	10.9
Namibia	6.1	60.5	33.4	13.2
Seychelles	2.4	86.3	11.3	6.3
South Africa	2.3	67.8	29.9	13.2
Swaziland	7.5	44.8	47.7	43.8
Tanzania	33.8	43.0	23.2	7.4
Zambia	9.6	56.5	33.9	8.2
Zimbabwe	12.0	56.9	31.1	12.8

Source: UNESCO (2015, p. 538)

Following the presidential elections of 2013, the incoming government set a new development plan, the Zimbabwe Agenda for Sustainable Economic Transformation (ZimAsset, 2013–2018). ZimAsset set out to rehabilitate and upgrade national infrastructure, including the national power grid, road and railway network, water storage and sanitation, buildings, and ICT-related infrastructure (ZimAsset, 2013). In 2017, the country's longstanding president, Robert Mugabe, was asked to resign, after being president for more than three decades. It was hoped his resignation would help solve some of the long-lasting economic hurdles faced by the country. However, the economy continued to be fragile, plagued by high external debt, degraded infrastructure, and an uncertain policy environment.

The African Development Bank reports that GDP in the country contracted by 12.8% in 2019, due to poor performance in the agriculture, mining and tourism sectors. Agriculture shrank due to natural disasters, prolonged drought, livestock diseases and currency shortages, which reduced the availability of inputs (African Development Bank, 2019). In 2018, following the country's general elections, the government launched the Transitional Stabilisation Programme (TSP). The programme's objective was to leverage the country's core competencies in natural resources (among other resources), and to rebuild and transform Zimbabwe into an upper middle-class economy by 2030. However, coupled with an austerity for prosperity agenda, the measures of the TSP crippled the economy. In 2016, the government introduced bond notes and coins, supposedly worth the same as the US dollar, but the notes steadily lost value. The exchange rate from the Zimbabwean dollar to the US dollar deteriorated from 2.5 Zimbabwe dollars per US dollar in February 2019 to 20 Zimbabwe per US dollar in November 2019. Inflation skyrocketed to 200% in 2019, caused mainly by the exchange rate movements and shortages of basic goods, including fuel and electricity (ibid.). Living standards for all citizens, from all sectors of society, have subsequently been in a downward spiral.

There continues to be a surge of students leaving the country to study. Table 2.15 shows that the number of Zimbabwean tertiary students studying abroad increased from 16 587 in 2013 to 19 104 in 2017.

Table 2.15: Total number of Zimbabwean tertiary students studying abroad, 2013-2017

Year	2013	2014	2015	2016	2017
Total number of students	16 587	16 484	17 082	17 977	19 104

Source: UNESCO Institute of Statistics (2020)

The top ten destination countries for 2017 are presented in Table 2.16. As can be seen, the majority of students, 11 247 (59%), enrolled in South African institutions. The next most common destination country – trailing far behind in the second position – was the United States at 1 365 (7%).

Table 2.16: Top ten destination countries of Zimbabwean students, 2017

Destination country	Total number of students	As % of 19 104 students in 2017
South Africa	11 247	59%
United States of America	1 365	7%
Namibia	1 118	6%
Australia	958	5%
United Kingdom	924	5%
Canada	618	3%
Malaysia	456	2%
Botswana	374	2%
India	335	2%
Ukraine	284	1%

Source: UNESCO Institute of Statistics (2020)
Note. Data for the following countries were missing - Burkina Faso, Belize, China, Costa Rica, Cuba, Algeria, Jamaica, Lebanon, Panama, Puerto Rico, Senegal, Singapore, and Togo were missing.

Since the preferred destination of Zimbabwean students is South Africa, a breakdown of the total number of students enrolled in South African universities by degree programme for the period 2009-2017 is provided in Table 2.17.[16] The table shows a significant increase over the years. For instance, the number of doctoral students enrolled in South African universities increased from 540 in 2009 to 2 493 in 2017.

Table 2.17: Total number of Zimbabwean students enrolled in South African universities, 2009-2017

Year	Total enrolments	All undergraduates	Postgraduates		
			Honours	Masters	Doctoral
2009	14 726	10 801	1 018	1 451	540
2010	19 814	14 817	1 333	1 694	696
2011	23 944	18 109	1 547	1 883	815
2012	26 267	19 949	1 157	2 021	989
2013	27 700	20 073	1 541	2 401	1 303
2014	27 481	19 384	1 500	2 754	1 638
2015	28 316	19 847	1 276	3 072	1 917
2016	26 403	17 654	1 149	3 224	2 282
2017	26 421	17 424	1 153	3 144	2 493
Average	**24 564**	**17 562**	**1 297**	**2 405**	**1 408**

Source: HEMIS Data: CREST

Table 2.18 shows the total number of Zimbabwean master’s and doctoral students enrolled in South Africa, between 2009 and 2017, in six broad fields. The table shows that the social sciences has the highest enrolment figures, followed by the natural sciences. The table also indicates that during the years under review, an average of 1 142 Zimbabwean master’s and 709 doctoral students were enrolled per year in the social sciences.

[16] Note that the total number of students in South African universities provided in Table 2.13 differs from the totals in Table 2.17 because two different data sources were used.

Table 2.18: Total number of master's and doctoral Zimbabwean students enrolled in South African universities, by fields, 2009-2017

Year	SS		NS		HU		HS		EN		AS	
	M	D	M	D	M	D	M	D	M	D	M	D
2009	707	210	187	141	168	70	129	32	175	30	85	57
2010	807	279	220	179	163	104	177	33	209	41	118	60
2011	906	333	259	197	155	116	206	48	243	52	114	69
2012	1 011	436	272	232	176	117	216	51	241	70	105	83
2013	1 159	642	347	250	267	153	240	85	264	70	124	103
2014	1 325	820	366	288	331	213	277	104	309	91	146	122
2015	1 463	1 020	366	280	368	223	350	139	371	102	154	153
2016	1 493	1 246	371	348	413	258	392	158	400	120	155	152
2017	1 405	1 391	365	377	429	265	405	167	402	130	138	163
Average	**1 142**	**709**	**306**	**255**	**274**	**169**	**266**	**91**	**290**	**78**	**127**	**107**

Source: HEMIS Data CREST
M=masters D=doctoral
SS=social sciences; NS=natural sciences; HU=humanities; HS=health sciences; EN=engineering, architecture and built environment; AS=agricultural sciences.

2.9 Conclusion

The chapter presented the setting for research in Zimbabwe. It provided information about the policy, institutional and socio-political environment within which research in Zimbabwe takes place. The country has a standing science policy that outlines measures taken by the government to encourage the development of scientific and technological research. The Office of the President, as the centre of power in the research system of the country, oversees the formulation, review, approval as well as implementation of the science policy. Within this office is a functional research agency (i.e. the Research Council of Zimbabwe). This council is mandated to promote, direct, supervise and coordinate research in the country. As with other countries in the region, Zimbabwe struggles to meet the target of allocating at least 1% of its GDP to R&D activities. From 2000, the country experienced various episodes of socio-political turmoil that affected all parts of society, including its knowledge production sector. During this period, a massive humanitarian crisis was experienced. The country lost research workers to neighbouring countries, notable to South Africa.

Information about the country's socio-political environment is relevant to the current study, as the socio-political periodisation (comprising four periods) was used in a time-based analysis of research production and collaboration in Zimbabwe. Instead of analysing the bibliometric data according to intervals of convenience (e.g. 5-year or 10-year intervals), the four socio-political periods were used for time-based analyses. In doing so, the (currently unknown) relations between the socio-political periods and research production and research collaboration in Zimbabwe will be revealed. Table 2.19 illustrates the three unknowns that the current study hopes to make explicit. The three unknowns are:

1. How do the four periods correspond to time-based differences in the research production of universities, sectors, and fields in Zimbabwe?
2. How do the four periods correspond to time-based differences in national research collaboration in universities, sectors, and fields in Zimbabwe?
3. How do the four periods correspond to time-based differences in international research participation in Zimbabwe's research, as reflected in international research collaboration and participation of INOs?

Table 2.19: Incorporating context to understand research production and research collaboration in Zimbabwe

Four socio-political periods	Three unknowns		
	Unknown 1	Unknown 2	Unknown 3
Period 1: Independence, vibrant economy, and neo-socialist policies Period 2: Adoption of Economic Structural Adjustment Programme (ESAP), natural disasters and global recession Period 3: Land reforms, sanctions, international isolation, and hyperinflation Period 4: Government of National Unity, years of recovery and slow economic growth	How do the four periods correspond to time-based differences in the **research production** of universities, sectors, and fields in Zimbabwe?	How do the four periods correspond to time-based differences in **national research collaboration** in universities, sectors, and fields in Zimbabwe?	How do the four periods correspond to time-based differences in international research participation in Zimbabwe's research, as reflected in **international research collaboration and participation of INOs**?

CHAPTER 3

Aspects of research production and research collaboration in the context of Africa

3.1 Introduction

The previous chapter outlined the policy, institutional and the general socio-political environment within which research in Zimbabwe takes place. This chapter focuses on the aspects of research production and research collaboration in the context of Africa as a whole. The chapter is divided into four main broad sections. Section 3.2 starts by highlighting the gross domestic expenditure on research and development (GERD) in sub-Saharan Africa. This section outlines the extent to which African countries invest in R&D activities, and how those funds are distributed across sectors. Section 3.3 highlights the findings of existing studies of research production or publication output in Africa. Section 3.4 discusses findings of studies of research collaboration in Africa. Included in this section is a discussion of the nature of regional and international collaboration in Africa; and a discussion of models of research collaboration involving developing countries. Finally, Section 3.5, reflects on methods used in the study of African research production and collaboration patterns.

Before discussing the aspects of research production and research collaboration in Africa, a reflection on the landscape in which research in Africa takes place is provided. According to Sooryamoorthy (2018), Africa has had a checkered history since the beginning of the independence of African countries in the 1950s. There have been ups and downs for science and scientific research as most of the countries in the region have gone through economic, social and political crises – which created a state of affairs Mouton (2008) described as the 'de-institutionalisation of science'. De-institutionalised science is characterised by weak scientific institutes (e.g. weak research centres and institutes, non-sustainable scientific journals, ineffectual scientific societies); dependence on international funding for research and development (R&D); individualism in research rather than institutional building; inadequate reproduction of the scientific and academic workforce; and weak inscription of science in African societies. According to Mouton (ibid.), the factors that contributed to this status quo, especially between 1980 and 2000, include the continuing legacy of colonial science in many African countries; the destabilising influence of political events and civil wars; the impact of World Bank policies on higher education in Africa; the role of international agencies in shaping African sciences; the continuing low investment in science by African governments; and the effects of the brain drain.

The potential for research is unevenly distributed amongst African countries (Gaillard, 1992). This is because African countries are at different levels and stages of scientific capacity and growth. To explain the different levels of scientific capacity and growth, Moed and Halevi (2014) proposed a bibliometric model of phases of scientific development. The model distinguishes four phases: (i) pre-development, (ii) building up, (iii) consolidation and expansion, and (iv) internationalisation. The first phase – pre-development – is characterised by low levels of research activity, low publication outputs, and low international co-authored articles. While it can be argued that a few African countries are still in the pre-development phase, as will be shown in Section 3.3, most have moved beyond this stage.[17]

The second phase – building up – is characterised especially by a large share of international collaboration. In this phase, researchers enter international scientific networks and collaborate with individuals from more developed countries. The percentage of international co-authored articles relative to a country's' total publication output begins to increase. As will be seen in Section 3.4, studies show that a large share of African science is produced in co-authorship with international partners (see e.g. Adams et al., 2010; Boshoff, 2009; Confraria et al., 2020; Mêgnigbêto, 2013; Owusu-Nimo & Boshoff, 2017; Sooryamoorthy, 2009).

It can be argued that most African countries, with the exception of countries such as South Africa and Egypt – the 'African scientific core' – have not yet reached the third phase of consolidation and expansion. In this phase, countries begin to develop their own scientific infrastructures. They allocate funds for research. National research capacities increase. National oriented journals internationalise and have probabilities of being indexed in mainstream bibliographic databases. Most research papers are based on research carried out by national institutions only. The number of international co-authored articles increases, but at a rate lower than that of the country's total output, hence the percentage of international co-authored papers declines. It has been noted, as will be discussed in Section 3.5.1, that African science is under-represented in mainstream databases. Coupled with that, in terms of publication outlets, African countries lack comprehensive local and regional bibliographic databases and infrastructure that facilitates the processing and dissemination of domestic scientific literatures (Mouton, 2008; Nwagwu, 2005). Furthermore, most institutions in Africa rely largely on international funding and collaboration to sustain their research systems

[17] Scholars have shown that Africa's research output, including articles produced through international co-authorship, has increased with time (see e.g. Adams et al., 2014; Boshoff, 2009; Confraria & Godinho, 2015; Confraria et al., 2020; Mouton & Blackenberg, 2018; Sooryamoorthy, 2018; Tijssen, 2007).

(Confraria & Godinho, 2015) (see Section 3.4.3). In this regard, Tijssen (2007) has questioned the notion of 'African science'.

The fourth phase and final phase– internationalisation – is characterised by an expansion in national research capacities. In this phase, a country's research institutions start functioning as fully-fledged. More of the institutions take the lead in international collaborations. The country's researchers begin to influence global research agendas. Countries begin to become world leaders in specific research domains. The number of publications and the share of international co-authored articles increase. Although the share of African articles produced through international co-authorship has increased in the past decades, this chapter will show (in Section 3.4.3) that research agendas for most African projects are steered by international funding partners.

The next section presents the gross domestic expenditure on research and development (GERD) in sub-Saharan Africa.

3.2 Gross domestic expenditure on research and development (GERD) in sub-Saharan Africa

In 2006, the African Science and Technology Consolidated Plan of Action (AU-NEPAD) proposed that African countries should commit at least 1% of their GDP to R&D activities. In response to this call, African countries committed to investing in R&D and to allocate 1% of their expenditure to R&D. However, African countries struggle to meet this target – most sub-Saharan African countries spend less than 0.5% of their GDP on R&D (Mouton, 2018). Sooryamoorthy (2018) notes that African countries have their own internal challenges regarding funds, resources and infrastructure for scientific research. These challenges affect their R&D activities. Table 3.1 shows the gross domestic expenditure on R&D (GERD) in selected countries in sub-Saharan Africa for 2011 or most recent year.

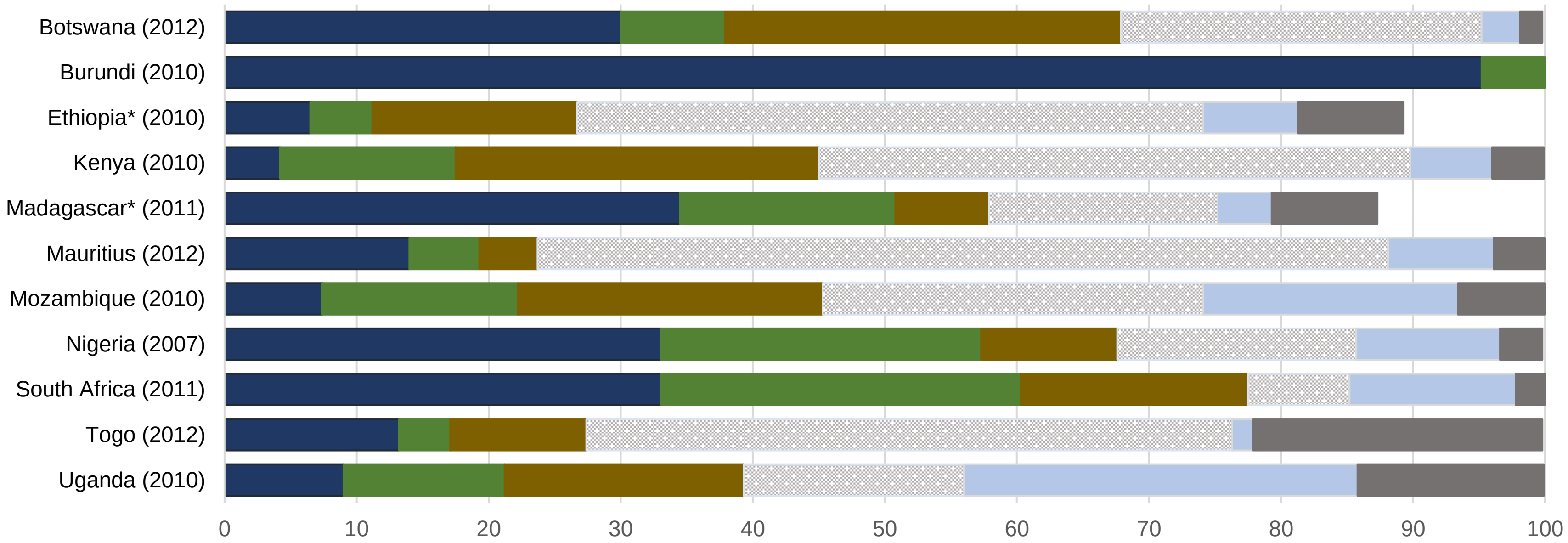
Table 3.1: Gross domestic expenditure on research and development (GERD) in sub-Saharan Africa, 2011 or closest year

Country	GERD (% of GDP)	GERD per capita current PPS$	GERD per researcher (HC) in current PPP$ thousands	GERD by source of funds (%)				
				Business	Government	Higher education	Private non profit	Abroad
Botswana (2013)	0.26	37.8	109.6	5.8	73.9	12.6	0.7	6.8
Burkina Faso (2013)	0.20	2.6		11.9	9.1	12.2	1.3	59.6
Burundi (2011)	0.12	0.8	22.3	-	59.9	0.2	-	39.9
Cabo Verde (2011)	0.07	4.5	17.3	-	100	-	-	-
Congo, Dem.Rep. (2009)	0.08	0.5	2.3	-	100	-	-	-
Ethiopia (2013)	0.61	8.3	95.3	0.7	79.1	1.8	0.2	2.1
Gabon (2009)	0.58	90.4	258.6	29.3	58.1	9.5	-	3.1
Gambia (2011)	0.13	2.0	59.1	-	38.5	-	45.6	15.9
Ghana (2010)	0.38	11.3	108	0.1	68.3	0.3	0.1	31.2
Kenya (2010)	0.79	18.8	62.1	4.3	26.0	19.0	3.5	47.1
Lesotho (2011)	0.01	0.3	14.3	-	-	44.7	-	3.4
Madagascar (2011)	0.11	1.5	13.3	-	100	-	-	-
Malawi (2010)	1.06	7.8		-	-	-	-	-
Mali (2010)	0.66	10.8	168.1	-	91.2	-	-	8.8
Mauritius (2012)	0.18	31.1	109.3	0.3	72.4	20.7	0.1	6.4
Mozambique (2010)	0.42	4.0	60.6	-	18.8	-	3.0	78.1
Namibia (2010)	0.14	11.8	34.4	19.8	78.6	-	-	1.5
Nigeria (2007)	0.22	9.4	78.1	0.2	96.4	0.1	1.7	1.0
Senegal (2010)	0.54	11.6	18.3	4.1	47.6	0.0	3.2	40.5
Seychelles (2005)	0.30	46.7	290.8	-	-	-	-	-
South Africa (2012)	0.73	93.0	113.7	38.3	45.4	0.8	2.5	13.1
Tanzania (2010)	0.38	7.7	110	0.1	57.5	0.3	0.1	42.0
Togo (2012)	0.22	3.0	30.7	-	84.9	0.0	3.1	12.1
Uganda (2010)	0.48	7.1	85.2	13.7	21.9	1.0	6.0	57.3
Zambia (2008)	0.28	8.5	172.1	-	-	-	-	-

Source: UNESCO Institute for Statistics (April 2015)
*Where figures do not sum to 100% for an indicator, this is because part of the data remain unattributed.
Note: Data are missing for some countries.

Table 3.1 shows that a few countries (i.e. Ethiopia 0.61%, Gabon 0.58%, Mali 0.66%, Senegal 0.54% and South Africa 0.73%) allocated at least 0.50% of their gross domestic expenditures on R&D activities. The table shows that for most of the countries in the region, the government sector is the main source of R&D funding. Some of the countries with the highest proportions of government funding are Botswana (73.9%), Ethiopia (79.1%), Mauritius (72.4%) and Nigeria (96.4%). The business sector contributes the smallest amounts to R&D. Countries where the business sector contributes more than 10% of GERD include Gabon (29.3%), Namibia (19.8%), South Africa (38.3%) and Uganda (13.7%). Foreign sources contribute significant amounts of GERD in countries such as Burundi (39.9%), Burkina Faso (59.6%), Kenya (47.1%), Tanzania (42.0%) and Uganda (57.3%).

Figure 3.1 shows the proportions of GERD allocated to broad fields of science in selected countries in sub-Saharan Africa. The figure shows that the natural sciences, agricultural sciences and medical sciences receive most of the funding for R&D, while the social sciences and humanities receive the least. The figure shows that in 2010, Burundi allocated almost all (95%) of its GERD to the natural sciences, and Botswana, Madagascar, Nigeria and South Africa invested at least 30% of their funding in the natural sciences. Ethiopia, Kenya, Mauritius and Togo allocated more than 40% of their GERD to the agricultural sciences. The figure illustrates that the health sciences also received substantial amounts of funding. Countries such as Botswana, Kenya and Mozambique invested at least 20% of their GERD in the health sciences fields.



	Uganda (2010)	Togo (2012)	South Africa (2011)	Nigeria (2007)	Mozambique (2010)	Mauritius (2012)	Madagascar* (2011)	Kenya (2010)	Ethiopia* (2010)	Burundi (2010)	Botswana (2012)
Natural sciences	9	13,2	33	33	7,4	14	34,5	4,2	6,5	95,2	30
Engineering	12,2	3,9	27,3	24,3	14,8	5,3	16,3	13,3	4,7	4,8	7,9
Medical and Health sciences	18,1	10,3	17,2	10,3	23,1	4,4	7,1	27,5	15,5		30
Agricultural sciences	16,7	48,9	7,7	18,1	28,8	64,4	17,3	44,8	47,4		27,3
Social sciences	29,8	1,6	12,6	10,9	19,3	8	4,1	6,2	7,2		2,9
Humanities	14,1	21,9	2,2	3,2	6,6	3,9	8	3,9	8		1,7

Figure 3.1: GERD in sub-Saharan Africa by field of science, 2012 or closest year (%)

*Where figures do not sum to 100% for an indicator, this is because part of the data remain unattributed.
Source: UNESCO Institute of Statistics (April 2015)

It can be seen, as illustrated in Table 3.1, that most sub-Saharan African countries spend less than 1% of their GDP on R&D activities. This explains why African countries rely on international funders for their R&D activities. (A detailed discussion of the reasons for the preference for collaborating with individuals from high income countries is provided in Section 3.4.2.) It can also be concluded, as shown in Figure 3.1, that the fields of agricultural, health and natural sciences receive more funding for research as compared to the fields of engineering, social sciences and humanities. The next section discusses Africa's publication output as well as publication output by field.

3.3 Publication output

One major indicator of the status of science is publication output (Sooryamoorthy, 2018). This measure indicates the production of science in a given country or region. To measure research capacity, scholars examine the research output contained in bibliometric databases. Several bibliometric studies have been performed to measure and map the status of science in Africa. These studies have shown that Africa's scientific research, as compared to that of the rest of the world, has always been low. Tijssen (2007) for instance, showed how sub-Saharan Africa fell behind in its contribution to world science output from 1% in 1987 to 0.7% in 1996. Tijssen indicated that this decrease did not necessarily mean a decrease in the absolute numbers of publications, but rather an increase slower than the worldwide rate. He stated that Africa lost 11% of its share of global science since its peak in 1987 and sub-Saharan science lost almost a third (31%) of its output. The UNESCO Institute of Statistics (2005) illustrated that Africa's contribution to global science during the period 1990-2002 was 1.4%. In another study, Pouris found Africa's share of global science output during the period 2000-2004 to be about 1.8%. In the same study, Pouris and Pouris (2009) observed that Africa's output during the period 2000-2004 was relatively lower than that of other developing countries; for example, while Africa's share was 1.8%, Latin America contributed 3.5% to the global research output during that same period.

However, despite having been recorded as contributing little to global scientific research, Africa's scientific output recently started to increase (Adams et.al., 2014; Confraria & Godinho, 2015; Mouton & Blanckenberg, 2018). Between 2003 and 2012, the sub-Saharan East African and West African regions more than doubled their share of global scientific output. For example, Southern African researchers produced 928 articles in 2001 and 1 940 in 2012; West and Central African researchers produced 3 069 articles in 2003 and 8 978 in 2012 (Blom et al., 2016). Similarly, Mouton and Blanckenberg (2018) found that Africa's share of world publication output doubled from 1.5% in 2005 to 3.2% in 2016, surpassing the world growth rate over that same period.

Scientific production in Africa is concentrated in a few countries; namely, South Africa, Egypt, Tunisia and Nigeria. These countries together with Morocco, Kenya and Tunisia account for 75% of all Africa's scientific papers (Tijssen, 2007). Using figures for 2000-2004, Pouris and Pouris (2009) found that South Africa was the primary producer of science in the continent. Likewise, Mouton and Blanckenberg (2018) found that between 2011 and 2015, South Africa, with a contribution of 28.2%, was the largest producer of science on the continent. Egypt, with a contribution of 19.6%, was the second largest producer during that same period.

Like the rest of Africa, publication output of countries in sub-Saharan Africa is concentrated in a few countries. In his study, Sooryamoorthy (2018) showed that between 2000 and 2015, South Africa, with a contribution of 45%, produced the bulk of scientific papers in sub-Saharan Africa. Nigeria followed, but at some distance, with a contribution of 11% (see Table 3.2). Six other countries were, in order of their productivity: Kenya (7%), Ethiopia (4%), and Tanzania, Cameroon, Uganda and Ghana all with contributions of 3%. Together, these eight countries accounted for 78% of the scientific papers produced in the region. Table 3.2 also provides disaggregated data for three periods for sub-Saharan Africa; namely, 2000-2004, 2005-2009 and 2010-2015. As can be seen, South Africa produced almost half of the scientific papers in the region across all three periods (47%, 44% and 44%, respectively). The table shows that some countries in the region are still in the pre-development phase, as indicated by the relatively low article output during the period under review. Countries such as Comoros, Eritrea, Djibouti, Sao Tome and Principe, and Somalia produced fewer than 100 articles each in periods 1 to 3.

Table 3.2: Publication output of countries in sub-Saharan Africa, 2000-2015

Countries	Total period		2010-2015		2005-2009		2000-2004	
	Count	%	Count	%	Count	%	Count	%
Angola	385	0.18	244	0.20	91	0.15	50	0.13
Benin	2 560	1.17	1 523	1.26	683	1.16	354	0.92
Botswana	2 308	1.06	1 071	0.89	719	1.22	518	1.35
Burkina Faso	3 054	1.40	1 731	1.44	830	1.41	493	1.28
Burundi	200	0.09	125	0.10	43	0.07	32	0.08
Cameroon	7 291	3.35	4 002	3.32	2 112	3.58	1 177	3.06
Cape Verde	128	0.06	102	0.08	21	0.04	5	0.01
Chad	244	0.11	107	0.09	90	0.15	47	0.12
Comoros	43	0.02	21	0.02	14	0.02	8	0.02
Congo	1 356	0.62	817	0.68	366	0.62	173	0.45
Djibouti	75	0.03	54	0.04	15	0.03	6	0.02
Eritrea	301	0.14	92	0.08	118	0.20	91	0.24
Ethiopia	7 819	3.39	4 763	3.95	1 844	3.13	1 212	3.15
Gabon	1 392	0.64	716	0.59	398	0.67	278	0.72
Gambia	1 413	0.65	669	0.56	414	0.70	330	0.86
Ghana	5 641	2.59	3 466	2.88	1 337	2.27	838	2.18
Guinea	2 127	0.98	1 096	0.91	543	0.92	488	1.27
Guinea-Bissau	369	0.17	184	0.15	102	0.17	83	0.22
Ivory Coast	0	0.00	0	0.00	0	0.00	0	0.00
Kenya	14 322	6.57	7 814	6.49	3 761	6.38	2 747	7.14
Lesotho	211	0.10	123	0.10	64	0.11	24	0.06
Liberia	108	0.05	103	0.09	0	0.00	5	0.01
Libya	1 795	0.82	1 014	0.84	512	0.87	269	0.70
Madagascar	1 430	0.66	1 196	0.99	0	0.00	234	0.61
Malawi	3 285	1.51	1 906	1.58	841	1.43	538	1.40
Mali	1 648	0.76	927	0.77	458	0.78	263	0.68
Mauritius	993	0.46	541	0.45	235	0.40	217	0.56
Mauritania	311	0.14	134	0.11	100	0.17	77	0.20
Mozambique	1 491	0.68	943	0.78	376	0.64	172	0.45
Namibia	1 300	0.60	708	0.59	364	0.62	228	0.59
Niger	1 063	0.49	596	0.49	293	0.50	174	0.45
Nigeria	24 004	11.02	12 437	10.33	7 839	13.29	3 731	9.69
Rwanda	919	0.42	714	0.59	165	0.28	40	0.03
Reunion	1 772	0.81	1 036	0.86	462	0.78	274	0.71
Sao Tome and Principe	27	0.01	15	0.01	2	0.00	10	0.13
Senegal	4 111	1.89	2 129	1.77	1 111	1.88	871	2.26
Seychelles	353	0.16	206	0.17	97	0.16	50	0.13
Sierra Leone	324	0.15	245	0.20	46	0.08	33	0.09
Somalia	37	0.02	28	0.02	6	0.01	3	0.01
South Africa	97 061	44.54	52 841	43.88	25 960	44.02	18 260	47.43
Sudan	3 070	1.41	1 862	1.55	763	1.29	445	1.16
Swaziland	397	0.18	242	0.20	99	0.17	56	0.15
Tanzania	7 367	3.38	4 110	3.41	2 077	3.52	1 180	3.07
Togo	711	0.33	376	0.31	192	0.33	143	0.37
Uganda	7 096	3.26	4 375	3.63	1 825	3.09	896	2.33
Zambia	2 379	1.09	1 400	1.16	607	1.03	372	0.97
Zimbabwe	3 603	1.65	1 630	1.35	972	1.65	1 001	2.60
Total	217 897	100	120 434	100	58 967	100	38 496	100

Source: Sooryamoorthy (2018)

Although the absolute volume of published papers is often used as an indicator of research activity, and indirectly of research capacity, it needs to be noted that countries have different features which affect the production of publications (Confraria & Godinho, 2015). For example, countries with large populations are more likely to produce more publications. The same goes for investments in research: countries with high proportions of GDP spent on R&D have a higher likelihood of producing more papers. This suggests that research publication output in any comparative study needs to be normalised by size of the population and other relevant factors such as GERD/GDP. In their study, Onyancha and Maluleka (2011) attributed South Africa's high article output to its scientific proficiency in terms of expenditure on R&D; the total number of its research workforce; and the high ranking of its universities. South Africa is reported to have spent about 1% of its GDP on R&D in 2006, while the rest of sub-Saharan Africa spent less than 1%. Adams et al. (2014) echoed these findings and showed that out of the leading countries by output (i.e. South Africa, Egypt, Nigeria, Tunisia, Algeria and Kenya), South Africa, Egypt, Nigeria and Algeria were also leading countries in terms of GDP.

3.3.1 Publication output by scientific field

Bibliometric studies show that the emphasis of research in Africa is on medical and natural resources disciplines. As illustrated in Figure 3.1, these two fields, together with the natural sciences, receive the highest proportions of gross domestic expenditure. Based on Web of Science (WoS) data, Pouris and Ho (2014) identified tropical medicine, parasitology and infectious diseases as the main research foci of Africa. Blom et al. (2016) showed that sub-Saharan Africa's output growth has generally been driven by advances in the health sciences. Blom and colleagues stated that with the health sciences accounted for an average of 45% of all sub-Saharan Africa research produced between 2003 and 2012. Two explanations for this growth are provided. Firstly, due to the tremendous health challenges the continent faces, improved Africa-relevant health research and well-trained health workers have a great impact on health outcomes. Secondly, the improvement in sub-Saharan Africa's research capacity in the health sciences demonstrated that persistent support and funding from development partners and governments pays off (ibid.). Scholars have, however, expressed concern about the overall skewing of African research towards health. For instance, Pouris and Ho (2014) commented on the fact that sub-Saharan research emphasises medical and natural resources to the detriment of disciplines that support knowledge-based economies and societies. Table 3.4 shows the output by subject groupings for sub-Saharan Africa's regions and South Africa, as presented by (Blom et al., 2016).

Table 3.3: Percentage of total article output by subject groupings for sub-Saharan Africa, 2012

	Southern Africa	East Africa	West and Central Africa	South Africa
Physical sciences and STEM	28.0	25.3	32.3	44.7
Agriculture	33.4	34.4	28.2	22.9
Health sciences	44.8	47.8	43.1	26.5
Social sciences and humanities	17.5	15.4	14.0	21.8
Life sciences	15.7	15.0	15.2	8.7

Source: Blom et al. (2016).

In a more recent study, Mouton and Blanckenberg (2018) showed that the fields that contributed significantly to world output between the period 2005 and 2015 were tropical medicine; parasitology; infectious diseases; water resources; ecology; immunology; zoology; plant sciences; and public, environmental and occupational health (see Table 3.3). These results reaffirm, as noted by Mouton and Blanckenberg (ibid., p. 17), “that scientific production often mirrors the material reality of a country or region” – in this case, the biodiversity on the continent as well as the need to invest in studying tropical and other diseases that plague many African countries.

Table 3.4: Scientific fields with highest contributions from Africa (in descending order for world share in 2015)

Field	% World share	Total number of publications (2005-2015)
Tropical medicine	24.71	7 380
Parasitology	15.85	6 643
Infectious diseases	13.22	13 183
Biomedical social sciences	8.01	1 889
Entomology	7.29	3 596
Ornithology	7.19	721
Andrology	6.77	250
Integrative and complementary medicine	6.41	1 770
Public, environmental, and occupational health	6.28	13 729
Agronomy	6.11	4 697
Planning and development	6.07	3 661
Soil science	6.02	1 670
Biodiversity and conservation	5.60	2 139
Mining and mineral procession	5.60	2 139
Agriculture, dairy and animal science	5.60	1 390
Mycology	5.58	3 152
Agricultural economics and policy	5.54	831
Medical ethics	5.45	499
Water resources	5.38	291
Crystallography	5.07	2 772

Source: Mouton and Blanckenberg (2018)
Note: Only the top 20 science fields were selected.

In his study on knowledge specialisation in sub-Saharan Africa, Onyancha (2018) found that sub-Saharan Africa's strength is in microbiology, immunology, agriculture and clinical medicine. He noted that research in the region is concentrated in the natural and agricultural sciences. Onyancha argued that most research investments in sub-Saharan African countries are channelled to research areas of interest to donors and/or relevant governments. Hence, the most resourced economic sectors such as agriculture and biomedical will continue to dominate the scientific landscape in the region. Furthermore, Onyancha noted that the concentration of research in sub-Saharan Africa favours natural and applied sciences as opposed to the social sciences and humanities. This trend is likely to continue, thus shaping the production of new knowledge in the fields of natural and applied sciences.

Research preferences and specialisation vary across countries and even across regions. For example, Narvaez-Berthelemot et al. (2002) reported that South Africa contributed immensely to medical fields, while Nigeria and Kenya's publications were concentrated in biology and clinical medicine. Later studies by Adams et al. (2010) and Confraria and Godinho (2015) noted similar findings and reported that Nigeria was prolific in agriculture, while South Africa and Egypt were leaders in the field of chemistry. Additionally, Sooryamoorthy (2018) found that for the period 2011-2015, South Africa's science revolved around (in order of importance): chemistry, environmental sciences, ecology, engineering, physics and science, technology, and other topics. Egypt, the second largest country in the production of science in Africa published most of its publications (in order of importance) in: engineering, physics, materials science, pharmacology, biochemistry, and molecular biology. Nigeria produced its highest number of publications in the following fields: general and internal medicine, pharmacology, environmental sciences and ecology, agriculture, engineering, and public, environmental, and occupational health. Kenya showed strength in seven fields: infectious diseases, environmental sciences and ecology, science, technology and other topics, agriculture, immunology, parasitology and tropical medicine.

The next section discusses the current state and circumstances of research collaboration in Africa, with a specific focus on sub-Saharan Africa, based on a review of the scholarly literature.

3.4 Research collaboration in Africa

Researchers in Africa engage in various forms of collaboration. These include between research groups within departments; between and within departments in the same institutions; between same or different institutions within countries; between countries in the same or different regions in Africa; and with groups and institutions outside Africa. Several studies have been carried out in Africa, both country-wise (e.g. Ghana – Owusu-Nimo & Boshoff, 2017; South Africa – Sooryamoorthy, 2009; CREST 2019) and regionally (e.g. Central Africa – Boshoff, 2009; Southern Africa – Boshoff 2010; West Africa – Mêgnigbêto, 2013; sub-Saharan Africa – Onyancha & Maluleka, 2011) to map the trends and patterns of research collaboration in Africa. Field-specific studies on research collaboration in Africa have also started to increase (e.g. engineering – Patra & Muchie, 2017; library and information science – Asubiaro, 2019; Maluleka & Ocholla, 2016; Onyancha, 2018; Social sciences – Sooryamoorthy, 2017). The findings of these and other studies are provided in the sections that follow. The review provided in this chapter is narrowed down to regional and international collaboration. Gaps in the literature are identified and discussed as such.

3.4.1 Nature of research collaboration in Africa

Bibliometric studies show that collaboration amongst African countries (intra-Africa collaboration) is weak (Adams et al., 2013; Boshoff, 2009; Onyancha & Maluleka 2011; Guns

& Wang, 2017). Where African countries do collaborate, the collaboration often involves a non-African country (Boshoff, 2009), or is mediated through cooperative health and agricultural initiatives (Adams et al., 2013). Adams et al. (2013) refer to the landscape of research collaboration in Africa as extremely complex and dependent on perspectives as much as on data. While some authors argue that researchers in Africa collaborate with others in their respective regions, other scholars put forward different perspectives. For instance, Onyacha (2011) argues that collaboration within Africa is remarkably regional, which means that researchers collaborate with others within their respective regions. Similarly, Toivanen and Ponomariov (2011) found low levels of inter-regional collaboration among the Southern-Eastern, West, and Northern regions:

> so great is the heterogeneity between these three regions and so weak are the inter-regional linkages, that it raises the broader question of optimal organisation of African research. Considering that African research effort and capacity are increasing rapidly, Africa stands at the risk to miss synergies inherent in well integrated innovation systems and which are foundational for knowledge economy (Toivanen & Ponomariov, 2011, p. 491).

Boshoff (2010), on the other hand, commented on the stronger cross-regional links between South Africa and countries like Kenya and Nigeria rather than with countries in the Southern African Development Community (SADC). Boshoff found that only 3% of SADC papers produced during the period 2005–2008 were jointly authored by researchers from two or more SADC countries, and that 5% of SADC papers were jointly authored with researchers from African countries outside the SADC. Likewise, Pouris (2017) found that of the 23 581 co-authored articles produced by South Africa between 2012 and 2014, only 563 (2.4%) were co-authored between South African and SADC co-authors, without non-African co-authors. In this instance, the main collaborating countries for South Africa were Zimbabwe (406 articles), Malawi (237 articles) and Namibia (221) (ibid.).

In a bid to explain the research patterns of countries, Narin et al. (1991) hypothesised that smaller countries may have fewer single country publications due to the scarcity of collaboration opportunities at the national level. The argument here is that collaborative efforts are initiated by researchers in small countries who cannot find collaborators. In this case, countries like South Africa with large science systems are likely to find collaborators within the country as compared to smaller countries with weak science systems. Similarly, Melin (2000) argued that researchers in large countries collaborate less internationally than smaller countries do as their scientists can more easily find research partners within national borders. On the other hand, Guns and Wang (2017) argued that countries with weak science systems have barriers of institutional mismatch; in other words, the structures and priorities of scientific research in those African countries can be very different from those countries outside of Africa. Thus, such countries collaborate with those with similar economic or institutional backgrounds. The research priorities in scientifically weaker African countries are also less compatible with those of international journals that are indexed in WoS or Scopus (ibid.).

3.4.1.1 Research collaboration in Africa by field

A few field-specific studies on research collaboration in Africa have been conducted (e.g. Asubiaro, 2019; Maluleka & Ocholla, 2016; Onyancha, 2018; Patra & Muchie, 2017; Sooryamoorthy, 2017). These studies highlight that collaboration, as demonstrated through co-authorships, has increased across all fields. Although fields such as the social sciences and humanities used to have lower levels of collaboration than the natural sciences (see Tsai et al., 2016), this status quo has since changed. Sooryamoorthy (2017) found that during the period 1970-2015, the level of collaboration in the social sciences in Africa was possibly equal to that of the natural sciences. Two out of three papers produced in the field of social sciences during that period were produced collaboratively. Previous studies in the natural sciences in South Africa also showed a similar pattern in collaboration (i.e. two out of four papers in the natural sciences were produced collaboratively). Of the collaborated publications in the social sciences, 63% consisted of domestic collaboration. There was more internal-institutional collaboration (44% of all domestic collaborated publications) than external-institutional collaboration (22% of all domestic collaborated publications) for the entire period. On a different note, Onyancha (2018) highlights that articles in the field of library and information science (LIS) are largely produced through co-authorship. Specifically, out of a total of 1 250 articles produced in LIS in sub-Saharan Africa between 1995 and 2016, 722 (58%) were co-authored while 528 (42%) were single-authored.

Regional and international collaboration is field specific. What this means is, while some fields produce articles through regional co-authorship, other fields generate most of their articles largely through international co-authorship. For instance, Pouris 2017 illustrated that for the period 2012 to 2014, articles produced by South Africa in co-authorship with African researchers occurred in disciplines different from those in which non-Africans participated. A comparative analysis of these two forms of collaboration is provided in Tables 3.5 and 3.6. Table 3.5 shows the research areas in which South Africa and SADC countries collaborate, which include non-African co-authors. Table 3.5 shows the most prolific research areas in the same cooperation efforts when there are no non-African participants.

Table 3.5: Research areas of collaborative research: South African authors with SADC co-authors (including non-African co-authors), 2012-2014

Research area	Number of publications out of 1 505
Infectious diseases	214 (14.2%)
Immunology	160 (10.6%)
Public, environmental and occupational health	131 (8.7%)
Environmental sciences and ecology	130 (8.6%)
Science and technology – other topics	109 (7.2%)
Agriculture	68 (4.5%)
Virology	64 (4.2%)
General & internal medicine	62 (4.1%)
Geology	56 (3.7%)
Microbiology	49 (3.2%)
Plant sciences	44 (2.9%)
Zoology	44 (2.9%)
Veterinary sciences	43 (2.8%)
Tropical medicine	41 (2.7%)
Astronomy and astrophysics	40 (2.6%)
Water resources	40 (2.6%)
Chemistry	39 (2.5%)

Source: Pouris (2017)

Table 3.5 illustrates that the medical and health sciences dominate the co-authorship list when South Africa and SADC countries collaborate with others outside Africa. However, when there is no non-African influence, co-authorship priorities change (see Table 3.6). Agriculture and environmental sciences and ecology are top of the list. Infectious diseases and immunology that were at the top of the list in Table 3.5 are lower down the list of Table 3.6. This means that areas such as infectious diseases and immunology appear to be led by foreign researchers. To this end, Pouris (2017, p. 3) raised several policy questions: “are the collaborative disciplines also induced by the non-African participants? If so, are they in the interest of the local regional system of innovation? What would happen if the non-African participants lose interest in the region? How can local collaboration be improved?”

Table 3.6: Research areas of collaborative research: South African authors with SADC co-authors (excluding non-African co-authors), 2012-2014

Research area	Number of publications out of 563
Agriculture	56 (9.9%)
Environmental sciences and ecology	44 (7.8%)
Public, environmental and occupational health	31 (5.5%)
Plant sciences	30 (5.3%)
Mathematics	25 (4.4%)
Engineering	24 (4.2%)
Physics	24 (4.2%)
Water resources	24 (4.2%)
Chemistry	22 (3.9%)
Geology	22 (3.9%)

Source: Pouris (2017)

3.4.1.2 Initiation and motivations for research collaboration

Research collaboration in Africa can be facilitated by several factors. Early studies identified language, culture and geographical proximity as the major drivers of African regional collaboration (see Adams et al., 2010; Boshoff, 2009; Onyancha & Maluleka, 2011). Adams et al. (2010) identified a French-speaking group formed around Cameroon and an English-speaking group including Nigeria, Ghana, Gambia and Kenya. Nigeria acts as a bridge between the two languages areas and also connects strongly to South Africa. Countries in the northern part of Africa, especially Egypt, also maintain unique links with those in their geographic proximity – in Egypt's case, Saudi Arabia (ibid.).

More recent studies have identified factors such as having worked together before, having the same research interests, or having a student-supervisor relationship as motivatons for reseach collaboration. Maluleka et al. (2016), for example found factors such as networking, sharing of resources, enhancing productivity, educating other students, overcoming intellectual isolation, reducing the time taken to complete projects, and learning from peers, as reasons for research collaboration in LIS in South Africa. In their survey about research collaboration in Ghana, Owusu-Nimo and Boshoff (2017) asked respondents to select from a list of potential factors how collaboration with individuals from three regions (namely, Ghana, the rest of Africa, and outside of Africa) came about. The study found that an already existing personal or working relationship influenced collaboration with researchers in all three specified regions. This reason was however more significant for those whose collaborators were in Ghana (82%), as opposed to elsewhere in Africa (41%) or in other parts of the world (46%). Having a student-supervisor relationship also seemed to initiate collaborations, especially collaborations with Ghana (46%) and collaborations outside Africa (38%). Similarly, Maluleka et al. (2016) found that mentee-mentor relationships fostered collaboration among LIS researchers in South Africa. Other factors identified as initiators of collaboration include having a mutual acquaintance, having existing partnership agreements between institutions, and collaboration being initiated by a funding agency (i.e. being part of the funding requirement) (Owusu-Nimo & Boshoff, 2017).

Regarding reasons for engaging in collaborative research, Owusu-Nimo and Boshoff (2017) found that access to expertise and the need to enhance productivity were the two main reasons for collaborating with colleagues within Ghana, in the rest of Africa and from outside of Africa. The authors also showed that researchers in Ghana collaborated with international researchers to improve chances of accessing funds, data or equipment, and in order to address the need for collective knowledge to tackle complex problems. Similarly, Muriithi et al. (2018) found that knowledge and resource-based factors – such as access to funding and special equipment, as well as collaborators having special skills and expertise – were ranked highly as motivations for collaboration by academics in Kenyan universities. Additionally, drawing on empirical data from the Young Scientists in Africa project, Mouton et al. (2018) found that young scientists from across Africa collaborated in research in order to obtain research funding, increase research productivity, learn from others, subdivide research activities, share resources, and promote interdisciplinary knowledge.

3.4.1.3 Challenges and barriers faced by African scientists when engaging in research collaboration

African scientists face a number of hurdles that hinder them from engaging in collaborative research. Mouton et al. (2018) identified a range of such obstacles including inability to find partners for collaboration, lack of resources, lack of funding, language barriers, and institutional barriers. In some universities, criteria for promotion and performance discouraged research collaboration. For instance, respondents revealed that university promotion rules did not encourage collaboration. Single authorship earns researchers full counts while co-authored articles are fractionally counted. This means that co-authored articles do not earn researchers full scores required for promotion and tenure.

With regard to Kenyan universities, Murriithi et al. (2018) grouped the collaboration problems faced by researchers into the following three dimensions: (i) problems of a socio-cultural nature, comprising items such as scientific competition, cultural differences, information security, resolving conflicts, authorship inclusion and order, diverse disciplinary training of collaborators, and selection of a publication forum; (ii) problems of management and control, which consisted of coordination of members' activities, timely delivery of results, defining roles, availability of time to commit to research, leadership and control, availability of skilled personnel, and administration of funding; and (iii) problems of availability of resources, consisting of ease of getting funding, amount of funding, and the availability of and access to special equipment. Of these three dimensions, problems of management and control and problems of availability of resources were cited as major issues. For example, lack of time to do research was rated highly as a problem in collaborative research. Additionally, lack of a research culture in Kenyan universities, where there tends to be a greater emphasis on teaching, was also cited as a challenge. With low budgetary allocations from government, one of the ways in which universities in Kenya survive is through huge student intakes, which are not proportional to the teaching staff (ibid.). This results in high teaching loads and the common complaint of a lack of time to do research. In terms of availability of resources, it was noted that generally there was low investment in research by the government. When funding is available, respondents cited the problem of administration of funds. In particular, participants pointed to the bureaucratic processes at the universities for the release of funds, which were reported to slow down progress and cause confusion for collaborators who were unfamiliar with how the university system works. In some instances, funds meant for research were diverted to other university projects considered more worthy (ibid.).

3.4.2 International research collaboration

In this section, the focus shifts to international research collaboration. Several studies show that science production in Africa is characterised by its high intensity in international collaborations. The numbers of articles produced in collaboration with researchers from outside of Africa have increased over time. Blom et al. (2016) showed that between 2003 and 2012, international collaborations as a percentage of Southern Africa's total article output increased from 61% to 79%. For Eastern Africa, international collaborations comprised between 65% and 71% of the region's total output. The three African countries that have shown the largest increases in interational collaboration are Egypt (from 27% in 2000 to 57% in 2015); South Africa (from 34% in 2000 to 52% in 2015) and Botswana (from 32% in 2000 to 77% in 2015) (CREST, 2019). In an early study, Boshoff (2009) found that the proportion of foreign co-authored papers was very high (more than 80% in scientifically 'small' countries of Central Africa). Boshoff also found that most African co-authors in Central Africa were mainly in charge of empirical fieldwork fieldwork and data collection. This phenomenon was also witnessed in three smaller countries – Uganda, Tanzania and Kenya (CREST, 2019)

One explanation for the high proportions of international collaboration, as reported by (CREST 2019), relates to the link between scientific fields and patterns of research collaboration. High collaboration intensity fields such as agriculture and health, are more likely to have high proportions of international collaboration (ibid). The other explanation for the high proportions of international collaboration is that, generally, African scientists prefer to collaborate with researchers from high income countries (Confraria et al., 2020; Guns & Wang, 2017). This preference is somewhat steered by a need to gain access to research infrastructure and funding, and to build research capacities and scientific networks (Confraria et al., 2020). Many of Africa's R&D organisations, specifically institutions in higher education, are largely dependent on foreign funding for their R&D performance. This funding is often linked to a northern based principal investigator (e.g. USA or EU), who by default is indicated as an international co-author of papers emanating from this research (CREST, 2019). The second Africa Innovation Outlook report (2014), see figure 2.2 in Chapter 2, shows that countries such as Mozambique, Burkina Faso and Uganda received more than 50% of their R&D funding from foreign sources. In their study on funding acknowledgemnts, Kozma et al. (2018) showed how non-African funders dominate research funding on the African continent.

The international countries collaborating most frequently with Africa are, in order, the United States (US), France, the United Kingdom (UK), Germany and Canada (Adams et al., 2014). These links are mainly mediated by language and colonial legacy. Schubert and Sooryamoorthy (2010) argue that colonial ties explain why the UK accounts for 29% of all South Africa's co-publications. Colonial ties also explain why 66% and 53% of Chad and Burundi's scientific output is accounted for by France and Belgium, respectively (Boshoff, 2009). Although the US never had any African colonies, its collaboration ties with Africa (as reflected in the bibliometric literature) can be attributed to African researchers who had studied in the US and continued to maintain their research groups abroad, even after returning to their home countries (Adams et al., 2014). The US ranks first in the case of South Africa, accounting for about 32% of all South African co-authored publications (Schubert & Sooryamoorthy, 2010).

The biggest collaborators in the field of LIS are, in order of importance, the US, UK and the Netherlands (Onyancha, 2018). The US, France and the UK are also the largest funders of research in biosciences, with more emphasis on medicine and agricultural sciences (Pouris & Ho, 2014). To this end, Pouris (2017) argues that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the continent. Additionally, non-African research funding steers how African scientists choose partners and topics (ibid.).

Recently, China has emerged as a prominent international collaborator of African countries. Eduan and Yuanqun (2019) revealed that China-Africa collaboration rose annually, from hundreds of documents in 2006 to more than 2 000 by 2016. Table 3.7 shows the top 20 African research partners with China from 2006 to 2016. The table illustrates that, with scores above 2 000, South Africa and Egypt are the leading collaborators of China. All other African countries scored below 1 000 documents.

Table 3.7: Top 20 African research partners with China, 2006-2016

Rank	Partner country	WoS		Rank	Partner country	WoS
1	South Africa	3 320		11	Ethiopia	151
2	Egypt	2 156		12	Uganda	147
3	Morocco	809		13	Tanzania	146
4	Nigeria	761		14	Zambia	83
5	Kenya	600		15	Malawi	71
6	Ghana	382		16	Zimbabwe	69
7	Sudan	348		17	Rwanda	62
8	Algeria	258		18	Cote Ivoire	59
9	Tunisia	239		19	Congo Dem. Rep	58
10	Cameroon	194		20	Sierra Leone	56

Source: Eduan and Yaunqun (2019).

3.4.2.1 Effects of international collaboration on Africa's research

Studies on research collaboration also discuss the effects of international research collaboration on African science (e.g. Boshoff, 2009; Dodsworth, 2019; Gaillard, 1994; Ishengoma, 2016; Schubert & Sooryamoorthy, 2010; Waardenburg, 1997). These studies highlight the positive and negative outcomes of North-South partnerships. Waardenburg (1997) for example, provided a analysis of North-South research collaborations and examines the strengths, weaknesses, opportunities and threats (SWOT) of such partnerships (see Table 3.8).

Table 3.8: A SWOT analysis of North-South research collaborations

Strengths	Weaknesses and challenges
• Northern and Southern partners can both benefit if collaborations are mutually negotiated between equals and are based on principles of reciprocity and joint agenda-setting. • Collaboration remains a reliable instrument for research capacity	• Power asymmetries undermine relationships. • Lopsided agendas prevent real collaboration. • Partners have incompatible goals and objectives. • Long-term perspectives and sustainability are lacking.
Opportunities	**Threats**
• Increasingly equal and balanced collaborations might emerge. • People might develop more insight into the challenges facing both North and South.	• Over-dependence on financial and technical support from northern donors imperils the sustainability and impact of collaborations, and ultimately undermines higher education in the South.

Source: Waardenburg (1997).

Relying on literature on research collaboration, Ordonez-Matamoros et al. (2011) proposed the following four arguments on the positive effects of international research collaboration on developing country's research productivity:

1. The "more-is-better" argument: It is argued that the division of labour enables more work to be done than would have been achieved single-handedly. In their study, Owusu-Nimo and Boshoff (2017) applied the "more is better" argument to explain why 51% of Ghanaian corresponding authors collaborated outside Africa.
2. The "complementarity-based-on-diversity" argument: This is largely the "strength of weak ties" argument proposed by Granovetter (2005), which claims that one has more to learn from those that see or have things that one does not see or have, than from those with similar characteristics. In other words, the value of collaboration lies in the differences between collaborators where one is perceived to have what the other is lacking. For example, Owusu-Nimo and Boshoff (2017) found that the main reasons for Ghanaian researchers' collaboration with individuals from outside Africa were to get access to collaborators' expertise (80%), funding (46%) and equipment (42%).
3. The "complementarity-based-on-epistemological-similarity" argument: This argument claims that for practical reasons, and to be successful in the research enterprise, one needs to collaborate with partners with whom one shares similar paradigms, methods, views and values. The argument also draws from literature that claims that personal empathy in terms of gender, age, social status, origin, language, ideology, experience, professional practice, professional ethos and religion is crucial. In this instance, the complementarity-based-on-epistemological-similarity argument can be applied to explaining why language, historical ties and culture shape international collaboration patterns. For example, Adams et al. (2014) showed that while France was more

strongly linked to its former French-speaking colonies in North-West and to Central West African countries, the UK also had strong ties with its former English colonies in East and Southern Africa.

4. The "linear-model" argument: This argument sees the collaborative process as an input-output process, where every collaborative input results in an S&T product.

Ishengoma (2016) summarised some benefits of North-South research collaboration. He said such partnerships:

- Promote knowledge production and the sharing of knowledge;
- Pool financial and human resources across national and regional boundaries;
- Give rise to synergies and complementarities among the diverse participants to their mutual benefit;
- Increase research productivity in Southern research institutions; and
- Give researchers in the south access to advanced research facilities.

However, as much as international research collaboration presents rewards for Africa, several scholars have written extensively about challenges faced by researchers, especially those in Africa. Gillard (2004) discussed the asymmetry of the relationship with and the dominance of partners from developed countries. Ishengoma (2016) highlighted that international research collaborations are dominated by Northern researchers via funding and agenda-setting. Knowledge exchange is limited since skill sets of the Northern and Southern researchers are seldom complementary. The dominant knowledge production is via controlled laboratory settings in which Northern research partners and funders define the research problems, methodologies, objectives and deliverables. Also, because research is seldom led by the demands of people or nations in the South, it is difficult to determine how relevant the knowledge produced is (ibid.).

3.4.2.2 Models of international research collaboration

This section presents the models used to explain collaboration between researchers in the North and those in the South. Different models have evolved over the centuries, from the age of the Enlightenment in the late 17th to 18th centuries, which have attempted to explain the growth and development of nation states. Modernism evolved after the Enlightenment and the dependency theory emerged from criticisms of the modernisation theory. The dependency theory had its own setbacks of elevating power relations and unequal partnership between supposedly hegemonic and dependent states. The world systems theory, described as an adaptation of the dependency theory, followed as an improvement on the dependency perspective as an approach to the problem of development in the least developed countries. For world-system theory, there is only one world, divided into the core, periphery and semi-periphery. The growth of international collaboration in African science using co-authorships has been examined in many cases along the theoretical lines of the core and periphery (e.g. studies by Boshoff 2009; Schubert & Sooryamoorthy 2010). Countries at the periphery follow the research designs of scientific work at the centre, which ultimately increases their capacity. The section that follows discusses the world systems theory and the semi-colonial and partnership models.

T*he world scientific core and periphery*

One of the problems with North-South partnerships, Gillard (2004) noted, is the asymmetry of the relationship and the dominance of partners from the developed countries. This asymmetry has informed the use of the dependency theory of core and periphery in studies of international scientific collaborations. But, is this model appropriate to explain the patterns of international collaboration between the North and the South? Boshoff (2009) noted that since the advent of modern science there has always been a world scientific core and, although this has shifted over time, at its heart is the ability to innovate and contribute to important scientific discoveries. Furthermore, the periphery has lacked such capacities. Boshoff noted, however, that apart from dependency theory, other schools of thought such as interdependency theory and institutionalism have also been used as approaches to explain scientific collaboration between North and South. Interdependency theory focuses on the positive growth that occurs in both the periphery and the core rather than on the inequality between the collaborators, while institutional theory, which examines isomorphism, seeks to explain the mimicking of western scientific models (see Mouton, 2008; Nagtegaal & De Bruin, 1994; Shrum & Shenhav, 1995).

Schott (1988), however, observed that the periphery's propensity to be influenced by the core could be explained in terms of geopolitics: political-economic affinity, language commonality and cultural cooperation. The influence of geopolitics was confirmed by Nagtegaal and De Bruin (1994), who found that international cooperation in science between the West and the Third World often follows neo-colonial patterns. The authors also found that sub-Saharan Africa was the scientific backyard, metaphorically speaking, of Western Europe, and that the intellectual domination of the West was growing rather than diminishing. Wagner and Leydesdorff (2005) brought together the different approaches used by researchers to explain the growth of international collaboration (see table below).

Table 3.9: Factors offered in the literature to explain the growth of international collaboration in science

Factors	Internal to science	External to science
Relating to the diffusion of scientific capacity	Centre-periphery dynamic of lagging countries seeking to cooperate with the leaders (Ben-David, 1971)	Official support for investment in research and development (Woolgar, 1991; Wouters, 1999; Mullins et al., 1977)
Relating to the interconnectedness of scientists	Internal disciplinary differentiation of science (Shils, 1988) Field-specific characteristics of 'big science' (Galison, 1987)	Historical relationships related to geographic proximity or colonial ties (Gibbons et al., 1994) Increase in international trade (KIM, 2002) Growth of information and communication technologies (Schott, 1991)

Source: Wagner and Leydesdorff (2005).

The approaches are split between those that consider the environmental factors in terms of internal and external factors. In addition, the approaches focus on the diffusion of scientific capacity or the interconnectedness of researchers.

- Diffusion of scientific capacity: Schott (1991), Ben-David (1971) and Shils (1988) see the progression of the diffusion of scientific capacity as related to a succession of countries that have acted as 'centres' for world science, with countries at the periphery (often smaller countries) trying to emulate the organisation, orientation and excellence of scientific work at the centre. The authors note that as the periphery emulates and adapts the practices of the core country, the capacity of their countries grows. Wagner et al. (2001) suggest that the increasing investment in R&D by governments and NGOs (such as the World Bank) – groups interested in using science as a tool to aid development – has also contributed to the diffusion of capacity.
- Interconnectedness of researchers: Reasons internal to science offered as explanations for collaboration include, for example, that collaboration arises from the dynamics of internal differentiation of science into specialised disciplines. The scale of investments in some fields is usually so large that no single nation could undertake it on its own (Galison, 1987). These field-specific characteristics make some collaboration unavoidable. This is the case with fields such as health and agricultural sciences. Mouton and Blanckenberg (2018) stated that the increase of the production of knowledge with international players relates to big science projects such as international health projects in global health. For example, Kahn (2018) showed that in the case of South Africa, the surge of international co-authorship was mostly the

results of these collaborative projects. Factors external to science offered as explanations for collaboration include: (i) geographic proximity and historical determinants (Zitt et al., 2000), and (ii) the rise of information and communications technologies as influencing the interconnectedness of everyone, not just those in the scientific community (Gibbons et al., 1994).

Semi-colonial model and partnership model

Costello and Zumla (2000) summarised the characteristics of two other models involving the North and the South; namely, the semi-colonial model and partnership model. The semi-colonial model, as the name depicts, has an unfair nature. The model pays little attention to ownerships, sustainability and the development of national research capacity of the South. It comprises of two forms: “postal/parachute research” and the “annexed sites”. Under postal research, researchers from developed countries in the North request colleagues in the South to collect data or courier biological samples to them. Parachute research occurs when researchers from the North travel to the South for short periods of time to ‘just’ take back biological samples. Research results are often published with minimal representation of researchers in the South. Results are also disseminated through publishing in international journals and conferences. The model seldom yields any positive effects on national institutions (ibid.).

The annexed sites model involves the creation of sites/centres at developing countries in the South. These sites are led and managed by researchers in the North/expatriate staff. Most of these sites produce innovative research, especially in tropical medicine, and several researchers in the South are trained there. Although researchers in ‘annexed sites’ may receive good training, only a few return to national institutions to contribute to national development. Most of the research conducted in these sites is not policy-oriented. In short, there is little that nations derive from such centres. Costello and Zumla (2000) argue that aligning the interests of these sites with national interests and encouraging collaboration with appropriate national partners would create mutually beneficial partnerships.

The partnership model involves true partnerships between researchers. Agenda-setting is negotiated between all the parties concerned. Here, research is managed by national representatives, and the dissemination of research output is balanced. The model has the greatest potential to yield positive effects, such as the building of local academic infrastructure.

3.5 Methodological approaches used to measure research production and research collaboration in Africa

This section reviews the literature on the methodological approaches used by scholars to measure and evaluate research output and research collaboration in Africa. The approaches discussed include: the use of mainstream bibliographic databases as sources for bibliometric data; application of context in the bibliometric analysis; the frequent use of article-level datasets as the main unit of analysis for bibliometric studies; use of international research collaboration as the single most prominent measure of international research participation in Africa; and the use of bibliometrics as the only measure for research collaboration in Africa. These methods and approaches also present research gaps in the current bibliometric studies of research collaboration in Africa. As already mentioned in Chapter 1, these gaps collectively constitute the research problem of the current study.

3.5.1 The use of mainstream bibliographic databases as the main sources for bibliometric data

Bibliometric studies frequently use mainstream bibliographic databases such as Scopus and WoS as the main data sources (see Table 3.10). This preference could be attributed to the fact that mainstream databases are seen as comprehensive, covering all fields of science. Although mainstream databases are frequently used to report on African science, such databases do not constitute a true representation of research conducted in the continent. For example, in an attempt to determine the extent of coverage of two universities – Moi University in Kenya, and the University of Zululand in South Africa – in Scopus and WoS, Ocholla et al. (2016) found that approximately 70% of academics at the two institutions were in neither of the two databases. This could mean that researchers in these institutions were either publishing less articles or publishing in journals that are not indexed in mainstream databases.

Galliard (1992) commented on the lack of representation of African journals in international bibliographic databases, with the result that African science is less visible in these databases. Mainstream databases are criticised for being biased in favour of journals from industrialised countries and towards topics in those countries (Ràfols et.al., 2016). Mainstream databases are also criticised for continuously excluding most journals from developing regions in their indexing. For example, the decline of the scientific contribution by sub-Saharan Africa from 1% in 1987 to 0.7% in 1996 was among other factors, attributed to discarding African journals from Thomson Reuters citation indexes (AU-NEPAD, 2010). It was reported that the number of South African journals indexed in the ISI indexes dropped from 35 in 1993 to 19 in 2004

(Ibid). This trend however, has since been reversed over the past years. For example, it is reported that in 2008, 21 or 3% of the Thomson Scientific list of 700 new journals were published in Africa (AU-NEPAD, 2010). Kenya and Nigeria contributed one journal each, while 19 originated from South Africa. Although this contribution was still relatively low, Onyancha (2009) observed that it was a positive departure from the records of previous years where the WoS only indexed 28 African journals up until 2006. Currently, more than 70 South African journals are indexed in the WoS and more than 100 in Scopus.

3.5.1.1 Alternative bibliographic databases

In response to the under-representation of African science in mainstream databases, scholars consult a broader range of alternative databases. The Institute de Recherche pour le Devéloppement (IRD) Centre for Development Studies (in France) has consistently utilised the **Pascal database**, particularly because of its broader coverage of Francophone countries in Africa. In a study of the social sciences, Narvaez-Berthelemot and Russell (2001) consulted the Database of Abstracts of Reviews of Effects (DARE). This database has a much larger coverage of social science journals than the WoS.

Some studies utilised **Google Scholar** as an alternative database (e.g. Onyancha & Ocholla, 2009; Ocholla, 2009). However, Google Scholar is said to come with its own set of challenges. Onyancha and Ocholla (2009) outlined limitations associated with Google Scholar, including: (i) it includes some non-scholarly citations such as student handbooks, library guides, editorials, news items and reviews; (ii) it does not index all scholarly journals; (iii) it does not cover all fields evenly (i.e. it has a better coverage of social sciences and humanities than the natural sciences); (iv) its automatic indexing results in errors such as double counting of citations or the appearance of different versions online; and (v) it is not updated as often as the ISI's WoS. Onyancha and Ocholla (ibid.) argue that the strength of Google Scholar, however, lies in the fact that it is affordable and easily accessible compared to WoS and Scopus, which are prohibitively expensive, especially for developing countries.

Considering the limitations that mainstream databases have **local journals and Institutional repositories** can be used as alternative data sources for bibliometric studies in Africa. Institutional repositories are digital archives of the intellectual product created by the faculty, research staff and students of an institution (Johnson, 2002). These archives are accessible to end-users both within and outside of the institution in open access platforms. Institutional repositories have numerous benefits for researchers in the African continent (Nyambi &

Maynard, 2012). They have the potential to improve access to scientific and technological data, information, and knowledge being generated in Africa. Their greatest advantage is that they offer an alternative strategic response to the existing problems in the current publishing system. These problems include delays in publishing articles, escalating prices of journal subscriptions, and high journal rejection rates in international journals for African scholars (Chisenga, 2006).

However, it also needs to be noted that institutional repositories (IRs) come with limitations, especially regarding classification of contents (Bangani, 2018). It is not always clear what is stored within IRs. In analysing South African IRs, Bangani (ibid.) found that there were no standards followed in terms of names given to IR collections. This could be true for many African universities that are still at their infant stages in the development of IRs. A challenge in lack of standards is seen, for instance, in that some public university IRs in South Africa tend to use conference papers and conference proceedings interchangeably, while it is common knowledge that the two are not the same. Some universities use the term ‘research output’ to refer to journal articles. Under journal collections, some institutions list journal articles while others differentiate between journal articles and journal volumes or issues (ibid.). There is also a perception that some of the contents in IRs are questionable and below standard. IRs are also characterised by stifled growth because of academics’ unwillingness to populate repositories without any clear incentives for doing so (Raju & Raju, 2009). Regardless of their limitations, it would be worthwhile exploring the added advantages, if any, of using IRs as bibliometric data sources to measure collaboration. Analysis of IRs would, however, require particular skills and expertise.

3.5.2 Application of context in the bibliometric analysis

Science in African countries is not homogenous in form, character, focus, application, direction and growth (Sooryamoorthy, 2009). Rather, it is a mixed set of research systems of varying size, human and physical resources, and governing structures (Tijssen, 2007). Considering Africa’s non-homogenous nature, it is likely that research output and collaboration patterns vary. To this end, Muriithi et al. (2018) argue that the nature and patterns of collaborative research depend on the context within which research is conducted and includes social, institutional, and technical environments. These environments differ according to regions, countries, institutions and fields, and even individual research teams.

Most African countries went through different socio-economic and political challenges in their independence phase. Most of these challenges led to the closing of scientific institutions, poor government funding for research and the plight of scientists to other parts of the world. Events such as the civil wars in Rwanda, Angola, Mozambique, the Mengistu regime in Ethiopia, and Idi Amin's dictatorship in Uganda had negative impacts on institutional development and, in many cases, led to the suspension of overseas research funding (Mouton, 2018). For example, Sida/SAREC suspended its support to Ethiopia in the late 1990s. As already discussed in Chapter 2, following independence in 1980, Zimbabwe also underwent a series of events that negatively affected all societal sectors, including human capital and R&D.

As was highlighted in Chapter 1, bibliometric analyses of African research seldom explicitly apply context in the analysis. Where context is applied, it is either done in the introduction to a study, where relevant R&D indicators or the prevailing research environment are discussed, or in a discussion of the profile of research systems and research organisations (e.g. Mêgnigbêto 2013; Owusu-Nimo & Boshoff, 2017). Notably absent is the incorporation of context in the analytic section of a study (e.g. analysing results in terms of a framework that mirrors the relevant conditions in a country or region). In some instances, context only appears in the discussion section to explain the patterns of collaboration. It is important to keep in mind that although bibliometric data analysis provides insights into science systems (i.e. research output and co-authorship patterns), such analysis is best understood within a country's unique context. Considering that African countries have different research infrastructures and different scientific developments, understanding the context in which research takes place would help explain research output and research collaboration.

3.5.3 Use of article-level datasets as the main unit of analysis

Hedt-Gauthier et al. (2019) note that the measurement of research collaborations is very complex. As such, Hedt-Gauthier et al. advise that collaboration behaviour could and should be described in terms of different dimensional properties; in other words, bibliometric studies on collaboration need to use more than one unit of analysis. However, common in most bibliometric studies is the use of a one-dimensional property (i.e. articles as the main unit of analysis). This is despite the fact that individual researchers, and not their articles, are the real sources of research activity. Individual researchers constitute the scholarly research workforce of a country as they contribute to original research in scholarly journals. Individuals are associated with departments, research groups, institutions, sectors and countries. Individual-level analysis can be applied to measure the productivity and networks of the research scholarly workforce and can also be used to track mobility of that workforce. Individual-level bibliometrics is a recent phenomenon in research measurement and has not yet been widely applied, especially in bibliometric studies on research collaboration in Africa. Based on scholarly literature, Boshoff et al. (2018) summarised discussions about individual-level bibliometrics. He summed up the four overlapping directions commonly followed in the literature as follows:

1. Context of research evaluation – where the interest of research evaluation is shifting from macro to increasingly lower levels of analysis.
2. Statistical properties of bibliometric indicators at the individual level – the focus here is on what each indicator expresses and the demands posed in terms of computation and data collection.
3. Technicalities involved in creating unique identifiers for individual-level bibliometrics.
4. Use of individual-level bibliometrics to investigate topics that appeal to science policy audiences as well as those in the sociology of science.

An example of an author-level bibliometric study for a developing country is provided by Boshoff et al. (2018), who identified Ugandan internationally-linked authors by focusing on four overlapping groups: authors with an international co-author; authors with a joint international affiliation; authors affiliated with an international organisation that has a local address, and authors affiliated with an international research partnership. Boshoff and his team reported that the most productive Ugandan authors were a small group who reported all four aforementioned forms of international linkages.

3.5.4 Use of international research collaboration as the single most prominent measure of international research participation in Africa

Bibliometric studies (e.g. by Adams et al., 2014; Boshoff, 2009; Boshoff, 2010; Confraria et al., 2020; Mêgnigbêto, 2013; Owusu-Nimo & Boshoff, 2017; Pouris & Ho, 2014) treat international research collaboration as the single most prominent measure of international research participation in the African research landscape. These studies typically measure international research collaboration based on bibliometric analyses of international co-authorship. International research participation generally involves large-scale research collaborations and collaborations between partners located within and outside Africa. These partnerships can be distinguished into two types (Dodsworth, 2019): firstly, North-South research partnerships, which occur when academics from high income countries collaborate with academics in developing countries in various research programmes; and secondly, partnerships between academics and non-academics. In the latter case, non-academics include national and international NGOs (which include multilateral aid agencies).

Multilateral aid agencies and NGOs and other international organisations often provide research funding for most African institutions. This means they can be mentioned in the funding acknowledgements of articles. Funding acknowledgments, in addition to analysis of international article co-authorship, have paved the way for new bibliometric measures of international involvement in research. Examples of such studies include those by Kozma et al. (2018), Wang and Shapira (2011), and Paul-Hus et al. (2016). What seems to be overlooked in bibliometric studies of international involvement in African research is the phenomenon of 'international national organisations' (INOs). INOs are international organisations or initiatives of international organisations (or set of organisations) that use an African country address in their publications. INOs tend to be adapted to the host country by supporting the research goals and research agendas of those countries. They appear as national organisations whereas they are, in fact, international organisations. In bibliometric studies of African countries, INOs can be erroneously coded as national organisations as they do not report their international address in publications but rather the address of their African host country. The previous section discussed international research co-authorship as a form of international participation in Africa. This section discusses INOs as another form of international participation.

International organisations that participate in North–South research collaborations take on different forms and thus they should not all be cast in the same mould. Four forms are intergovernmental organisations, INOs, partnerships of international research centres, and international businesses, and these are discussed in turn below.

Intergovernmental organisations: These are supra-level organisations comprised primarily of sovereign states. Intergovernmental organisations are established either by treaties or by an agreement that acts as a charter creating the group of organisations. The United Nations (UN) with its many specialised agencies (e.g. Food and Agriculture Organisation [FAO] and the World Health Organisation [WHO]) is an example of an intergovernmental organisation. As one of the specialised agencies, the WHO, with its headquarters in Geneva, Switzerland, operates in more than 150 countries around the world. It has a system of regional and country offices, each headed by WHO representatives. Its African region comprises 47 member states with the regional office in Brazzaville in the Republic of Congo. The WHO conducts research directly through its own staff but also commissions research for others to perform (Terr & Van der Rijt, 2010). Commissioned research can take the form of contract research where the WHO defines the research question, or the form of grants to institutions, fellowships and individuals. At times, the WHO also guides or advises research by being part of a network or partnership. Its main areas of work in Africa include health sector development and combating infectious and non-infectious diseases.

International non-governmental organisations: Non-governmental organisations are a second type of organisation associated with international research participation. Unlike intergovernmental organisations that are formed by states, NGOs are non-profit organisations that are not government entities, and which can be either international or local. International NGOs, when operating in countries outside their headquarters, are usually managed by local people with some assistance from parent organisations. On the other hand, local NGOs are run by local people but are largely dependent on foreign resources (Ng'ethe, 1991). Examples of international NGOs include the Elizabeth Glaser Pediatric Aids Foundation (EGPAF); World Vision; and Médecins Sans Frontières (MSF) (Doctors without Borders). As an international NGO, EGPAF is involved in health research in Africa. Its headquarters are in Washington in the US. The organisation supports activities in 19 countries, 16 of which are in Africa. EGPAF's research activities are located in its Global Research Unit, which works closely with country-based staff, ministries of health, and other partner organisations.[18]

Partnerships of international research centres: The third type of INOs are partnerships of research centres. Such partnerships occur when international research organisations partner with institutions in Africa for research purposes. Most of these partnerships are in the field of agriculture, and the most common is the Consultative Group on International Agricultural Research (CGIAR), which was formed in 1971. Currently there are 15 CGIAR centres, five of which are headquartered in sub-Sahara Africa, while the rest are outside of Africa. The network was established to create agricultural science centres of excellence to deal with food insecurity and related agricultural development issues, especially in the poorest countries of the world.

CGIAR brings evidence to policy makers, innovation to partners, and new tools to harness the economic, environmental and nutritional power of agriculture.[19] In contrast to staff at intergovernmental organisations who, in most cases, are seconded to a particular country

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[18] EGPAF website: https ://www.pedaids.org/focus/our-programs/, accessed February 2020.
[19] CGIAR website: www.cgiar.org, accessed March 2020.

programme but whose long-term security remains with headquarters, staff at the individual CGIAR centres “have no larger organizational home beyond their own center” (Herdt, 2012, p. 188). Each centre has its own charter, board of trustees and staff. The centres appear to be an ideal instrument for developing a stream of new agricultural technology. According to Herdt (ibid., p. 187), they have long been ‘qualified’ to receive foundation grants; have outstanding leadership and staff who can write good proposals; have research facilities in the poorest developing countries; and have access to local agricultural researchers.

Examples of CGIAR centres include the Centre for International Forestry Research (CIFOR) with its headquarters in Indonesia; International Crops Research Institute for Semi-Arid Tropics (ICRISAT), headquartered in India; and the International Maize and Wheat Improvement Center (CIMMYT), headquartered in Mexico. Some researchers have shown how these centres play central roles in improving agricultural output; for example, Konato et al. (2020) discuss how the ICRISAT helped improve groundnut production in Burkina Faso. Others show how the centres partner with internal players; for example, Boddupalli et al. (2020) account for how the CIMMYT, in close partnership with national and international partners, implemented a multi-disciplinary and multi-institutional strategy to curb the spread of maize lethal necrosis (MLN) in sub-Saharan Africa, and mitigate the impact of the disease.

International businesses: The fourth form of international participation in Africa is international businesses. Khan (2006) defines international businesses as businesses that work across the frontiers of two or more nations. An example of an international business involved in Africa’s research is the KMPG International Cooperative, headquartered in the Netherlands. It is one of the ‘big four’ accounting organisations, which consist of Ernst & Young, Deloitte, KPMG and PricewaterhouseCoopers. The four organisations offer accounting services to clients (i.e. auditing, corporate finance, taxation, actuarial, etc.). KPMG has firms in more than 147 countries across the globe. Each of these firms is an independent entity and a member of the KPMG cooperative. Although the firms are headquartered in the Netherlands, each national branch uses the name of its country – such as KPMG South Africa or KPMG Kenya.

Whatever the type of INO, their research activities cannot escape the prevailing research conditions and influences in the host country of operations. International national organisations also exert influences over the existing research environment, with a view to bringing about positive change.

3.5.5 Use of bibliometrics as the main measure for research collaboration

Studies on research collaboration in Africa commonly use bibliometric analysis of co-authored articles as the main measure of collaboration. Katz and Martin (1997) attribute the wide usage of bibliometrics to the ease of accessing the data and analysis. Van Raan (2005) says the wide usage of the method emanates from the assumption that scientists who have something important to say publish their work in international journals. However, he notes that this may not always be the case since journal articles may not be the only output for research collaboration, and journal articles do not always guarantee the existence of collaboration. Similarly, Smith and Katz (2000) warn that using co-authorship as a measure of collaborative activity must be treated with caution because:

> there are many cases of collaboration that are not consummated in a co-authored paper and which are consequently undetected with this approach. Conversely, there are other cases of, at best, only very peripheral or indirect forms of interaction between scientists which nonetheless yield co-authored publications (Smith & Katz, 2000, p37).

Using co-authorship as the only measure of research collaboration has several limitations. Co-authorship does not capture the full range of social dynamics experienced in research collaborations (Tsai et al., 2016). It does not tell the whole story in terms of the role of research-related experiences on subsequent choices, including choices about whether to collaborate, with whom to collaborate, and how to collaborate (Bozeman et al., 2016). To this end, Subramanyam (1983) advised that researchers need to adopt holistic perspectives when studying research collaboration. Researchers acknowledge that studies on research collaboration should preferably not rely on only one methodology, but rather can benefit from an expansion of methodologies. This might mean blending bibliometrics with surveys and interview methods. The latter methods allow for the exploration of details about collaboration patterns and experiences not captured by bibliometric analysis.

It is noted that most bibliometric studies on research collaboration in Africa seldom incorporate other data sources to reflect on research collaboration (e.g. survey or interview data). Studies that usually report different methods are large projects such as the Young Scientist study conducted by researchers at the Centre for Research on Science and Evaluation (CREST) (2018), and the Science and Technology and Higher Education in the SADC Region project (2007) also conducted by CREST. The Young Scientist project, for example, employed bibliometrics, a web-based survey and a series of qualitative interviews to profile Africa's scientific production and networks, for the period 2005 and 2015, with a focus on young scientists in the region. Other reports of this nature are country studies by UNESCO (e.g. UNESCO 2014, 2015).

However, in journals, articles seldom report different methods. A few exceptions are studies by Confraria et al. (2020) and Owusu-Nimo and Boshoff (2017). Both these articles incorporated self-reported survey data into their bibliometric studies. Generally, bibliometric studies appear as stand-alone studies (i.e. not blended with other data sources) because data for the studies are easy to access and analyse (Katz & Martin, 1997). The justification for the over-reliance on bibliometric studies in studying research collaboration stems from the fact that significant contributions to science appear in published research (the key focus of bibliometric studies). Table 3.10 shows a list of at least 20 bibliometric studies on research collaboration in Africa published between 2010 and 2020. It is important to note that journal articles focusing on Africa that include the words collaboration or co-authorship in the title were selected. The table shows that most of the studies (15 out of 20) used bibliometrics as the only method to measure collaboration, while three studies supplemented bibliometrics with the survey method.

Table 3.10: Methods and data sources used by researchers to investigate research collaboration in Africa, articles published between 2010 and 2020

Author	Title	Method	Data source
Asubiaro and Badmus (2020)	Collaboration clusters, interdisciplinarity, scope and subject classification of library and information science research from Africa: An analysis of WoS publications from 1996 to 2015	Bibliometric analysis	WoS
Confraria et al. (2020)	Which factors influence international research collaboration in Africa?	Bibliometric analysis and survey	WoS
Eduan and Yuanqun (2019)	Patterns of the China-Africa research collaborations from 2006 to 2016: A bibliometric analysis	Bibliometric analysis	WoS
Muchie and Patra (2020)	China–Africa science and technology collaboration: Evidence from collaborative research papers and patents	Bibliometric analysis, social network analysis	WoS
Chiware and Becker (2018)	Research trends and collaborations by applied science researchers in South African universities of technology: 2007–2017	Bibliometric analysis	Scopus
Onyancha (2018)	Mapping collaboration and impact of library and information science research in sub-Saharan Africa, from 1995 to 2016	Bibliometric analysis	WoS
Sooryamoorthy (2017)	Do types of collaboration change citation? A scientometric analysis of social science publications in South Africa	Bibliometric analysis	WoS
Pouris (2017)	The influence of collaboration in research priorities: The SADC Case	Bibliometric analysis	WoS
Owusu-Nimo and Boshoff (2017)	Research collaboration in Ghana: Patterns, motives, and roles	Bibliometric analysis and survey	WoS
Guns and Wang (2017)	Detecting the emergence of new scientific collaboration links in Africa: A comparison of expected and realized collaboration intensities	Bibliometric analysis	Scopus
Fari and Ocholla (2016)	Nature, patterns and trends of research collaboration in selected universities in Nigeria and South Africa	Bibliometric analysis	Scopus
Finardi and Buratti (2016)	Scientific collaboration framework of BRICS countries: An analysis of international co-authorship	Bibliometric analysis	Scopus
Landini et al. (2015)	The structure and dynamics of networks of scientific collaborations in Northern Africa	Bibliometric analysis	WoS, PATSTAT-CRIOS database
Pouris and Ho (2014)	Research emphasis and collaboration in Africa	Bibliometric analysis	WoS
Adams et al. (2014)	International collaboration clusters in Africa	Bibliometric analysis	WoS
Mêgnigbêto (2013)	International collaboration in scientific publishing: The case of West Africa (2001-2010)	Bibliometric analysis	WoS
Onyancha and Maluleka (2011)	Knowledge production through collaborative research in sub-Saharan Africa: How much do countries contribute to each other's knowledge output and citation impact?	Bibliometric analysis	WoS
Sooryamoorthy (2011)	Collaboration in South African engineering research	Bibliometric analysis	WoS
Toivanen and Ponomariov (2011)	African regional innovation systems: Bibliometric analysis of research collaboration patterns 2005–2009	Bibliometric analysis	WoS
Boshoff (2010)	South-South research collaboration of countries in the Southern African Development Community (SADC)	Bibliometric analysis	WoS

Note: Journal articles focusing on Africa, which include the words 'collaboration' or 'co-authorship' in the title, were selected.

Besides the use of bibliometric analysis as the only measure for research collaboration in Africa, a few studies used a self-reported survey as their only method to profile research output and research collaboration in Africa. Examples of such studies are by Maluleka et al. (2016), who investigated the factors that influence research collaboration in LIS schools in South Africa; Breet et al. (2018), who analysed academic and scientific authorship practices of South African researchers; and Muriithi et al. (2018), who examined the factors that influence research collaboration among academics in Kenya.

Other than the use of the survey method to examine research collaboration in Africa, other scholars used qualitative methods. For example, Sooryamoorthy (2014) used face-to-face interviews to study the relationship between publication productivity and collaboration of South African science academics at two higher education institutions, and Dodsworth (2019) carried out a literature review to discuss the challenges of making research collaboration in Africa more equitable.

3.6 Conclusion

The conclusions drawn from the chapter are summarised under the following headings:

3.6.1 Publication output

Studies showed that Africa's scientific research output as compared to that of the rest of the world has always been low. The relatively low output was attributed to a number of factors, among which were limited funding, poor infrastructure, and a shortage of qualified researchers. However, despite having been recorded as contributing little to global scientific research, studies have shown that Africa's scientific output has recently started to increase. This could be attributed to, among other factors, African researchers' increased engagement in collaborative research.

Sub-Saharan Africa's output growth has been driven by advances in the health sciences. To this end, scholars have expressed concern that African research tends to be skewed towards health, to the detriment of disciplines that support knowledge-based economies and societies. Its strength is in fields such as microbiology, immunology, agriculture, and clinical medicine. Since most research investments in sub-Saharan African countries are channelled towards the research interests of donors and/or relevant governments, the most resourced economic sectors such as agriculture and biomedical will continue to dominate the scholarship landscape in the region. Research preferences and specialisation vary across countries. South Africa's science revolves around (in order of importance): chemistry, environmental sciences and ecology, engineering, physics and science, technology, and other topics.

Nigeria’s strength is in general and internal medicine, pharmacology, environmental sciences and ecology, agriculture, engineering, and public, environmental, and occupational health, while Kenya’s strength is in infectious diseases, environmental sciences and ecology, science, technology, agriculture, immunology, parasitology, and tropical medicine.

The concluding questions raised in this section were:

- Do sub-Saharan African countries specialise in the fields that focus on their societal needs and/or challenges? Or,
- Should societal needs not matter at all when it comes to the governments’ research priorities?

3.6.2 Research collaboration

Collaboration, as demonstrated through co-authorship, has increased across fields and sectors. More and more articles, including those in fields such as the social sciences and humanities, are increasingly being produced through co-authorship.

Collaboration among African countries is weak. In instances where African countries collaborate, collaboration is often initiated by a non-African country or mediated through cooperative health and agricultural programmes. Generally, science production in Africa is characterised by its high intensity in international collaborations. There is little co-authorship between African countries, with preference being given to collaboration with researchers from high income countries. This preference is somewhat steered by a need to gain access to research infrastructure and funding, and for building research capacities and scientific networks.

The biggest international collaborators of Africa are the US, France, the UK, Germany and Canada. These links are mainly mediated by language and colonial legacy. Although the US never had any African colonies, its collaboration ties with Africa (as reflected in the bibliometric literature) can be attributed to African researchers who had studied in the US but continue to maintain their research groups abroad, even after returning to their home countries. The US, France and the UK are the largest funders of research in biosciences, with greater emphasis on medicine and agricultural sciences. It may be concluded that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the continent.

3.6.3 Methodological approaches used by researchers to measure research production and research collaboration in Africa

Finally, the chapter highlighted methodological approaches employed by scholars to measure and evaluate research output and research collaboration in Africa. These are:

- The use of mainstream bibliographic databases as data sources for bibliometric analysis. Although mainstream databases are constantly used to evaluate African science, it is argued that such databases under-represent research conducted in the continent. This is the case because researchers in Africa prioritise research that addresses local needs such as poverty, food security and disease control. Such research is published in local journals and does not often find its way into international mainstream journals. In response to the under-representation of African science in mainstream databases, researchers have used alternative data sources. Untapped sources are local journals and institutional repositories. Regardless of their limitations, it would be worthwhile exploring the added advantage, if any, of using IRs as bibliometric data sources to measure collaboration.
- The use of article-level datasets as the main unit of analysis. Several studies use the article-level dataset as the main unit of analysis. However, this is despite the fact that individual researchers, and not their articles, are the real sources of research activity. Individual researchers constitute the scholarly research workforce of a country as they contribute to original research in scholarly journals. Scholars need to explore different units of analysis, such as author-level datasets tailor-made for specific countries.
- Bibliometric analyses of African research seldom explicitly apply context in the analysis. This is despite the fact that collaborative research depends on the context within which research is conducted, and includes social, institutional and technical environments. These environments differ according to regions, countries, institutions and fields, and even individual research teams.
- Bibliometric studies treat international research collaboration as the single most prominent measure of international research participation in the African research landscape, with little attention to additional measures (i.e. international national organisations) tailored for the African context.
- Bibliometric studies of African research seldom incorporate other data sources to reflect on research collaboration (e.g. survey or interview data). Studies on research collaboration cannot sufficiently rely on one methodology but can rather benefit from

an expansion of methodologies. This might mean blending bibliometrics with surveys and interview methods.

CHAPTER 4
General perspectives on research collaboration

4.1 Introduction

Research collaboration, as demonstrated through co-authorships, has increased across fields and sectors. Several reasons have been given to explain this upsurge, including the increasing complexity and interdisciplinarity of research; the ease of collaboration made possible by increased mobility and new robust technological infrastructure; and cross-national funding programmes that incentivise the sharing of personnel and resources geographical boundaries (Sugimoto. & Larivière, 2018). There has been increasing interest among researchers and within policy circles in the notion of research collaboration. Numerous initiatives and policies aimed at improving the links between science and technology through fostering research collaboration across sectors have been developed. Scientific collaboration has become an important component of science, technology and innovation policy with resources allocated by governments for this reason (Pouris, 2017). Governments' involvement in collaboration programmes is based on the recognition that research does not stand alone but requires collective efforts.

Researchers have investigated different facets of research collaboration. Basic questions include, for instance, what constitutes a collaboration? Who are the collaborators? With whom do researchers collaborate and why? What effects do collaborations have? Some studies have been concerned with the measurement of the phenomenon. Here, research collaboration is often operationalised using co-authorship and sometimes data generated from the acknowledgement sections of publications. Others have analysed the growth of the phenomenon in different aggregate levels; namely, at individual, group, department, institution, sector and national levels. Generally speaking, the literature on research collaboration is quite extensive, and dates back to the early 1960s.[20]

Bozeman et al. (2013) provided an organising framework for the research collaboration literature (see Figure 4.1). The scholars identified three main attribute categories that are frequently analysed in the literature: (i) collaborator attributes, (ii) attributes about the collaboration process in general, and (iii) specific organisational or institutional attributes. Each

[20] Examples of early studies include Beaver and Rosen (1979), Clarke (1964), Price (1963), and Price and Beaver (1966).

of these categories contains subcategories that further organise literature into a cohesive framework that contributes to the understanding of the relationship between additionality and research and development (R&D) impacts.

The framework proposed by Bozeman et al. (2013) is used as a guide to organising the discussion of the literature on research collaboration in this chapter. The aim of this chapter is to provide an overview of the general perspectives on research collaboration. Guided by the model, Section 4.3 discusses the motivations for research collaboration and how personal collaborator attributes (e.g. age, sex, career stage, and nationality) influence choices of collaborators. Section 4.4 discusses the collaboration process and composition, with a focus on the factors that affect the collaboration process. Finally, Section 4.5 discusses collaboration outputs, with a main focus on article authorship disputes.

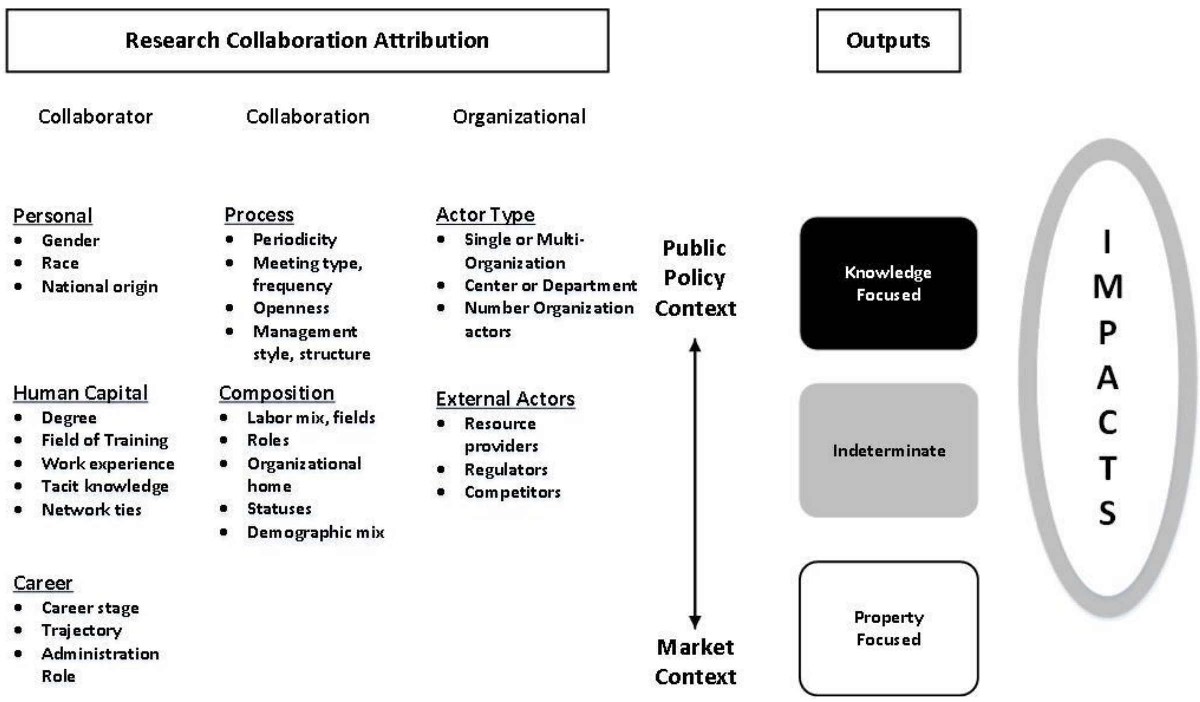

Figure 4.1: Framework for organising research collaboration literature

Source: Bozeman et al. (2013, p. 6).

The first category in the framework (i.e. collaborator attributes) concerns studies that focus on the individual level collaborator attributes in the collaboration process. Many of these studies (e.g. Bozeman & Gaughan, 2011; Lee & Bozeman, 2005; Ponomariov & Boardman, 2010) aimed to answer the question: who collaborates with whom? This question is answered by identifying personal attributes of collaborators such as gender, race and national origin (as shown in the first column in Figure 4.1). Other studies (e.g. Bozeman & Corley, 2004; Lee & Bozeman, 2005) focused on the human aspects such as training or experience that collaborators bring to the collaboration team. Bozeman and Corley (2004), among others, focused on the career stages of the collaborators as an important factor of collaboration.

The second category in the Bozeman et al. (2013) framework (i.e. collaboration attributes) concerns studies that examined research collaboration processes and composition. Most of these examined how the attributes of collaborative groups interact and affect collaboration activities and outcomes (e.g. Abramo et al., 2011; Beaver, 2001; Cummings & Kiesler, 2005).

The third category (i.e. organisational/institutional attributes of research collaboration) is concerned with studies that focused on the macro level organisational and institutional attributes of the collaborators. Most of the studies in this category focused on the process of university/industry partnerships, and on how the organisational arrangement influences research policy (e.g. Cummings & Kiesler, 2005; Fox & Mohapta, 2007). Other articles focused on issues emerging from collaborations among researchers working in different universities. Finally, the last column in the framework categorises articles that focused on outputs and impacts from research collaborations (e.g. Boardman & Ponomariov, 2007; D'Este & Perkmann, 2011; Siegel et al., 2003), and articles that focused on ethical issues and the 'dark side' of research collaboration (i.e. co-authorship disputes; crediting and management issues).

Before discussing the motivations, research collaboration process and the research collaboration outcomes, the chapter begins by outlining definitions of research collaboration provided in the literature (Section 4.2), the levels and types of research collaboration (Section 4.3), and the measurement of research collaboration (Section 4.4).

4.2 Definitions of research collaboration

The existing literature on research collaboration shows that there is no common definition of research collaboration. Smith and Katz (2000) argue that research collaboration is neither well understood; nor is the term consistently applied. Katz and Martin (1997, p. 11) propose that research collaboration could mean "the working together of researchers to achieve the common goal of producing new scientific knowledge." However, they elaborate that "working together" is relative; in other words, the term does not define the type of contribution that would qualify an individual as a collaborator. On the one hand, it can be argued that anyone providing an input to research should be considered a collaborator; on the other hand, it can also be argued that only those who contributed directly to all the main research tasks over the duration of the project should be termed collaborators (Katz & Martin, 1997). Inasmuch as it is difficult to identify where collaboration falls on the spectrum, Katz and Martin conclude that research collaboration lies somewhere between the two extremes. They suggest a criterion to distinguish ‘collaborators’ from other researchers. In this definition, collaborators might then include (ibid., p. 12):

- Those who work together on the research project throughout its duration or for a large part of it, or who make frequent or substantial contributions;
- Those whose names or posts appear in the original research proposal;
- Those responsible for one or more of the main elements of the research (e.g. the experimental design, construction of research equipment, execution of the experiment, analysis and interpretation of the data, or writing up the results in a paper);
- Those responsible for a key step (e.g. the original idea or hypothesis, the theoretical interpretation); and
- The original project proposer and/or fundraiser, even if his or her main contribution subsequently is to the management of the research (e.g. as team leader) rather than to the research per se.

The group of collaborators would exclude “those who make only an occasional or relatively minor contribution to a piece of research; and, those not seen as, or treated as, ‘proper’ researchers (e.g. technicians, research assistants)” (ibid.). Katz and Martin further elaborate that while their criterion for distinguishing between collaborators and other researchers may apply in many research circumstances, exceptions to virtually all the suggested criteria can be easily identified. They state that collaboration has a fuzzy or ill-defined border, and “exactly where that border is drawn is a matter of social convention and is open to negotiation” (ibid., p. 13).

A narrower view of research collaboration is provided by Laudel (2002, p. 5), who suggests that research collaboration is “a system of research activities by several actors related in a functional way and coordinated to attain a research goal corresponding with these actors’ research goals or interests.” Laudel clarifies that a ‘shared goal’ is not a necessary premise for collaborative work; and, what defines collaboration is the ‘activities’ and not necessarily the ‘actors’ involved in a collaborative process. She states that it can be decided (as suggested by Katz & Martin, 1997) whether non-researchers such as fundraisers, technical assistants or other people contributing to the collaboration's success should be considered as collaborators. Based on the above definition, Laudel (2002) offers variations of research collaboration; namely, collaboration involving division of labour, service collaboration, transmission of knowledge, provision of access to research equipment, mutual simulation, and trusted assessorship.

Similarly, Lewis et al. (2012) comment on researchers' 'activities' in the collaboration process. They argue that although academics across disciplines undertake collaborative activities, not all collaboration has the same level of visibility. To address the problems posed by a tendency for analysis to be biased towards the more visible (and easily measurable) forms of collaboration, Lewis and her team proposed an analytical distinction between Collaboration with a capital 'C' and collaboration with a small 'c'. They argued that 'Collaboration' is where researchers work together on a research project, designing it and/or undertaking the project together, and publishing on its results together. On the other hand, 'collaboration' involves discussion of research and ideas, feedback and commentary on research work and draft papers.

Other definitions of research collaboration stress the social context of research collaboration and its place within the scientific community. Sonnenwald (2007), for example, argued that scientific collaboration is the interaction of two or more researchers taking place within a social context, which facilitates the sharing of meaning and completion of tasks with respect to a mutually shared and superordinate goal. Another example is Bozeman et al. (2013), who defined the concept as a social process whereby human beings pool their human capital for the objective of producing knowledge. By this definition, Bozeman and his team implied that collaboration needs not only be focused on publishing articles, since generally research collaboration is operationalised using co-authorships. They argued that collaborations are often more concerned with technology development, software or patents and may have no publication objective at any point. In other words, collaboration can occur without a co-authored paper being produced.

What is common in all the definitions provided above is the concept of interaction and working together to produce knowledge. However, given that collaboration is an intrinsically social process, scholars still face difficulties in establishing what really constitutes a collaboration, and how closely researchers would need to work in order for the interaction to constitute a collaboration. Having presented the various definitions of research collaboration, the next section focuses on understanding different levels of research collaboration.

4.3 Levels and types of research collaboration

According to Katz and Martin (1997, p. 15), research collaboration can be explored at several levels – "between two or more individuals, between research groups within a department, between departments within the same institution, between institutions, between sectors and between geographical regions and countries." Importantly, collaborations mainly occur between individuals. It is individual scientists who participate in collaborative projects and not departments or institutions (Smith & Katz, 2000). Although individual researchers are the fundamental unit in a collaborative process, more attention is usually given to collaboration at macro levels (ibid.). Despite the lack of attention at these levels, Smith and Katz (ibid., p. 92) consider fostering collaboration at the interpersonal level as important as the other levels, as "meaningful collaborations are almost always driven from the bottom-up and from within the research process itself." Additionally, ties based on personal working relationships and interests are more likely to endure beyond the lifetime of an individual project, as compared to those pegged on material needs which usually end when the collaboration comes to end.

In addition to categorising six levels of research collaboration (i.e. individuals, groups, departments, institutions, sectors and countries), Katz and Martin (1997) note that research collaboration can occur either between or within different levels. The prefixes 'inter' and 'intra' distinguish between these levels. For instance, *inter*national collaboration means collaboration between nations while *intra*-national collaboration means collaboration within a single nation. Collaboration may also appear to belong to both an intra and an inter category. To this, Katz and Martin point that collaboration can either be homogenous (i.e. either inter or intra form of collaboration) or heterogeneous (i.e. a mixture of the inter and intra forms of collaboration). Table 4.1 shows the various levels of collaboration; the distinction between inter and intra forms of collaboration and examples of scholars who examined collaboration at each aggregate level.

Table 4.1: Different levels of collaboration and distinction between inter and intra forms

Level	Intra	Inter	Source
Individual	-	Between individuals	Kretschmer (1994); Iglic et al. (2017); Melin (1999); Newman (2004)
Group	Between individuals in the same research group	Between groups (e.g. in the same department)	Bozeman & Corley (2004); Bozeman & Gaughan (2011); Gaughan & Bozeman (2016)
Department/ discipline	Between individuals or groups in the same department	Between departments (in the same institution)	Lewis et al. (2012)
Institution	Between individuals or departments in the same institution	Between institutions	Glanzel & De Lange (1997)
Sector	Between institutions in the same sector	Between institutions in different sectors	Leydesdorff & Etzkowitz (1996)
Nation	Between institutions in the same country	Between institutions in different countries	Panomariov & Boardman (2016); Glanzel & Schubert (2004); Schubert & Sooryamoorthy (2010)

Source: Katz and Martin (1997)

While Katz and Martin (1997) categorise six levels of research collaboration, Subramanyam (1983) about four decades ago, remarked that collaboration in research takes many forms of activity, ranging from offering advice and opinions to active and sustained participation, and contribution of physical and intellectual resources. Subramanyam cited Heffner (1981), who characterised collaboration as being theoretical (i.e. rendering advice, ideas or criticism) or technical (i.e. providing tangible assistance in a research endeavour). Heffner also distinguished between co-authors (i.e. those who share authorship of a publication) and sub-authors (i.e. those who are not co-authors, but whose assistance in the research project is acknowledged in a publication). Such assistance might be theoretical, technical or even financial.

Roper (2002) distinguishes different types of collaboration. Roper highlights four categories for classifying types of collaboration; namely, scope, coverage, originators, and the extent of involvement of the individuals concerned. Two typologies, in his view, are the expert-consultant model and the expert-trainer model, where academics are poised to be role models, and whose functions are to identify and promote standards of organisations through the production, learning and sharing of skills and knowledge. Building on these perspectives are Sullivan and Skelcher (2002), who highlight three types of collaboration; namely, contracts, networks and partnerships. Sullivan and Skelcher note that contracts are collaborative initiatives built upon formal agreements, based on a principal-contractor relationship which can be terminated in the event of the violation of contract terms. Large international organisations such as the World Health Organisation (WHO) commonly commission research which takes the form of contract research. Sullivan and Skelcher (ibid.) consider networks as connections which begin with ordinary relationships, driven by willingness, mutual trust and common benefits. Networks go beyond organisational boundaries and are more advantageous in terms of individual participation. Partnerships are joint mutual agreements. They are characterised by joint agenda-setting and decision-making processes and joint operations.[21]

Sullivan and Skelcher (2002) argue that the typology of collaboration is likely to belong to one or more of three theoretical viewpoints; namely, optimist, pessimist or realist. The optimist viewpoint advocates the partnership of different parties involved in carrying out a project aimed at solving a common problem through the implementation of shared responsibilities and mutually-oriented initiatives for long-term benefits. Academics and practitioners stride side by side with mutual and shared responsibilities from the beginning to the end of the collaboration process (ibid.). Partnerships which fall under this paradigm can be between groups, institutions or nations.

The pessimist perspective is the opposite of the optimist viewpoint. The motive behind collaboration in the pessimist paradigm is to be the dominant influence of the parties involved. The theory is derived from resource dependency theory as proposed by Pfeffer and Salancik (2003). The collaborative norms emphasised in this theory are competitive in nature, and the parties involved use their resources and influence in order to control others as well as to manipulate and control their reputation (Fari & Ocholla, 2016). The theory emphasises dominance and control. Several studies (e.g. Boshoff, 2009; Dodsworth, 2019; Ishengoma, 2016) have shown how some countries, especially those which own resources, dominate others during the research collaboration process. Control of others usually occurs when some parties are made to do the bulk of the work. There may also be instances where some parties are excluded as co-authors after having put in work. For example, Boshoff (2009) showed how, during collaborations, developing countries fall prey to dominant developed countries. Boshoff (ibid.) surveyed 82 reprint authors from France, the United Kingdom (UK) and the United States (US), enquiring about the nature of the research contributions made by co-authors from Cameroon, a developing African country. The study found that approximately 80% of reprint authors said that the Cameroonian co-authors helped with the fieldwork or data

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[21] For a comprehensive discussion on research partnerships between the North and the South, see Dodsworth (2019).

collection, and 60% said that they helped with the interpretation of results. He also noted that African co-authors were mainly in charge of empirical fieldwork and data collection, and most of the projects were conceptualised and designed in the Global North. To sum up, the pessimist paradigm views collaboration as an opportunistic venture. Collaboration can be embarked on at any stage of the research project inasmuch as the perceived benefits of dominance and resource control are certain (Sullivan & Skelcher, 2002). Fari and Ocholla (2016) argue that such collaboration has risks exceeding benefits as actors pursue collaboration through self-interested strategies.

The realist viewpoint focuses on the prevailing situation at the time of a collaborative project as the basis for making informed decisions about the participation and level of involvement in the project. This paradigm is similar to the evolutionary theory put forward by Alter and Hage (1993). The idea is that several factors such as politics, economy, technological advancements and partners influence the viability of a collaborative initiative. The paradigm views collaboration as a relative practice evolving through practice (Sullivan & Skelcher, 2002).

Broader types of research collaboration are provided by Wagner et al. (2001), who organise the different types of collaboration around those involving large science projects and international players. They noted that there are different types of collaboration which, in turn, create different management requirements (see Figure 4.2). The figure illustrates two axes that can describe different organisational forms of collaboration. The vertical axis runs from spontaneous ‘bottom up’ research deriving from the interests of scientists, to highly organised research defined by a funding party. The horizontal axis plots the degree of centralisation of the effort. The two axes form four quadrants which together characterise collaborative research. Activities on the left side of the diagram are described as ‘dynamic’ in that the collaboration requires active learning and sharing of tasks and information among researchers who are often geographically dispersed. Activities on the right side are described as material/institutional research in that collaboration relies on a shared resource or common research location. Mega science projects could be placed in the bottom right quadrant as organised and centralised. Scientist-initiated research would be placed in the upper left quadrant (ibid.). Figure 4.2 also shows examples of organisations and projects examined by Wagner et al.

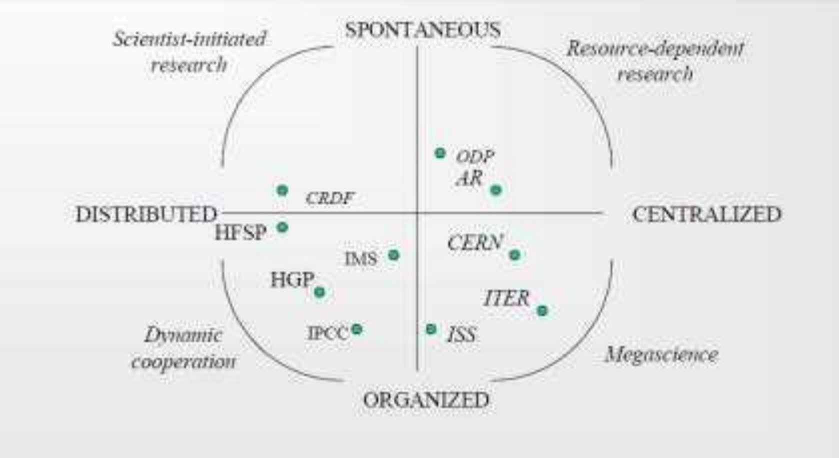

Figure 4.2: Types of research collaboration

Source: Wagner et al. (2002)

Note: HFSP=Human Frontiers Science Program; HGP=Human Genome Project; AR=Arctic Research; IMS=Intelligent Manufacturing Systems; IPCC=Intergovernmental Panel on Climate Change; CERN=European Organization for Nuclear Research ; ITER (fusion research); ;ISS=International Space Station; AR=Arctic research; ODP=Ocean Drilling Program; CRDF=Cooperative Research and Development Fund

This section has highlighted that research collaboration can be considered in a variety of contexts. It varies across different settings (e.g. disciplines, social groupings, institutions and individuals), and relies on interpersonal networks and sets of interactions between individuals which can take on many forms. It can also be categorised into different types, and theoretical perspectives can be applied to explain these different types. While some scholars look at collaboration at higher levels such as between nations, institutions, laboratories and research groups, it needs to be emphasised that the fundamental unit of research collaboration is the individual: it is individuals who carry out research and who constitute the research workforce. The next section focuses on how scholars measure research collaboration and how collaboration is distinguished from co-authorship.

4.4 Measuring research collaboration

In previous chapters (i.e. Chapter 1 and Chapter 3) it was highlighted that most studies on research collaboration in Africa, apart from large science projects such as the Young Scientist study (see Beaudry et al., 2018), and a few articles (e.g. by Confraria et al., 2020 and Owusu-Nimo and Boshoff, 2017), use bibliometric analysis of co-authored articles as the only measure for research collaboration. The focus in this section is on studies on research collaboration outside of Africa. The aim is to identify the methods most commonly used and to understand why this is the case. Outside the African context, three methods have dominated studies of research collaboration; namely, count of published articles derived from bibliometric databases, self-reported surveys, and written papers and publication counts obtained from self-constructed vitae (Ynalvez & Shrum, 2011). Of these methods, publication counts in international databases have been the most widely used, with initial studies dating back to the 1950s. Katz and Smith (1997) note that Smith (1958) was one of the first researchers to observe an increase in co-authored papers and to suggest that such papers could be used as a proxy measure for collaboration. Other early advocates for the use of co-authored articles as a measure of changes in collaboration were Price (1963) and Price and Beaver (1966). Co-authored papers have since been widely used as a proxy for research collaboration. The reasons for the widespread use of co-authored articles to examine collaboration are many and could, among other factors, include the fact that bibliometric data are relatively easy to access and analyse (Katz & Martin, 1997); that co-authorship is the most tangible and documented indicator of collaboration (Glanzel & Schubert, 2004); and that bibliometric analysis of co-authorship identifies nearly all aspects of collaboration (ibid.).

Despite the widespread use of co-authorship as a proxy for research collaboration, studies argue that using co-authorship as the only measure of research collaboration has several limitations. Melin and Persson (1996) argue that co-authored articles are not the only output that research collaboration produces and that co-authorship does not guarantee the existence of collaboration. Co-authorship does not capture the whole picture of collaboration activities; it represents a specific type of collaboration with its roots mainly in the write-up process (Katz & Martin, 1997). Furthermore, co-authorship is associated with several risks when conducting bibliometric analyses – for example, misallocating names and incorrectly identifying the location and geographic interactions of co-authors with multiple institutional affiliations. However, although the assessment of collaboration using co-authorship is by no means perfect, it nevertheless has advantages. It is invariant and verifiable; practical for quantifying collaboration; viable for large samples; and is unobtrusive and non-reactive, meaning it does not affect the collaboration process (Katz & Martin, 1997; Subramanyam, 1983).

One conclusion that can be drawn from the arguments presented above is that although co-authorship is a strong indicator for collaboration, it does not usually represent all aspects of collaboration. Furthermore, considering that collaboration is a socio-cognitive process, it involves equipment and laboratories, as well as human beings (Sooryamoorthy, 2010). For that reason, knowledge of the relationship of collaboration to tangible outputs such as publications, while quite useful, is not usually sufficient (Bozeman et al., 2016). Although publication is important for almost all collaborators, it is typically only one among several motives for collaboration. Other motives include mentoring and developing scientific and technical human capital (Bozeman & Corley, 2004); obtaining a stream of research support

(Bozeman & Gaughan, 2011); and contributing to institution building (Ponomariov & Boardman, 2010). Bozeman et al. (2016) state that when collaborators make contemporaneous judgments about collaboration effectiveness, publication outcomes are almost never among the 'earliest returns'. Collaborators do not suspend judgment about the effectiveness of collaboration or the value of collaborators while they await acceptance of research for publication or other relevant outcomes such as conference placement. Early judgments have strong psychological framing effects and they affect later decisions. Furthermore, publication does not necessarily give insight into the collaborators' assessment about whether the work achieved its potential. Such assessments are achieved through the use of surveys and interview methods.

A number of studies have supplemented the bibliometric method with surveys. Tsai et al. (2016), for example, combined bibliometric data with survey data. The authors argued that survey data allows for the exploration of details about collaboration patterns and experiences that cannot be captured by only focusing on co-authorship data. By combining the two methods they were able to measure collaboration as co-authorship, the social dynamics of collaborative teams, as well as the disciplinary differences in collaboration norms and practices. Iglic et al. (2017) also used both bibliometric and survey methods to understand the reasons why Slovenian researchers engaged in research collaboration. Iglic and his colleagues remarked that the use of interviews and surveys in research collaboration studies has value too. In particular, these methods allow scholars to measure collaboration by obtaining information from researchers, who are asked to describe aspects of their collaborations with others.

Some studies relied only on semi-structured interview data to measure research collaboration (e.g. Bozeman et al., 2016; Gaughan & Bozeman, 2016). Bozeman et al. (2016) used semi-structured interviews to understand the research collaboration experiences of US academic researchers. Their interview guide solicited information about faculty researchers' characteristics; the nature of research collaborations; decision-making processes for determining authorship and author-order; the role of policies such as promotion and tenure; and information about positive and negative research collaboration experiences. Their interview protocol allowed for flexibility to adapt to each interview subject's situation.

Studies by Lee and Bozeman (2005) and Bozeman and Corley (2004) used only the survey method to measure research collaboration. Bozeman and Corley (ibid.) identified participants by studying the CV database of the university researchers associated with the US National

Science Foundation. Lee and Bozeman (2005) noted that focusing on the collaboration rather than the publications provided a means by which to include important collaborations whose outputs were not publications. Surveys are advantageous as they rely on the researcher's idea of a significant collaboration rather than on externally imposed concepts.

Melin (2000), on the other hand, used both interview and survey methods to understand the reasons why scientists engage in research collaboration. Melin identified several advantages of using interviews in research collaboration studies. For instance, personal and emotional details can be revealed through interviews. Interviews provide an understanding of what researchers think about the collaborative situation, how they interact and what the practice of collaboration really looks like. Also, through interviews, respondents are able to reveal their opinions and details according to their own self-experienced collaborations.

Despite the advantages of using survey and interviews methods, it is important to note that these methods also have their own disadvantages. Subramanyaman (1983, p. 35) summarised that the precise nature and the "magnitude of collaboration cannot be easily determined by the usual methods of observation, interviews or questionnaires given the complex nature of human interactions that take place between and among collaborators over a period of time." In addition, the nature and magnitude of the contribution of each collaborator are likely to change during the course of a research project. Subramanyam (ibid.) proposed that researchers need to adopt holistic perspectives when studying research collaboration; in other words, the study of research collaboration can benefit more from a combination of data collection methods. The weakness of one method can be complimented by the strength of another.

4.5 Motivating factors for research collaboration

A number of reasons have been identified as motivating factors for research collaboration. These factors occur at either the micro (i.e. individual) or macro (i.e. structural) levels. At the individual level, collaboration is motivated by reduced costs in travel and communication, together with the impact of electronic media which has enhanced collaborative research efforts (Beaver & Rosen, 1979; Katz & Martin, 1997); and accessibility of expertise, skills and equipment that enable researchers to explore and exploit complex societal issues (Beaver, 2001; Heinze & Kuhlmann, 2008; Katz & Martin, 1997; Melin, 2000; Sooryamoorthy & Shrum, 2007). Research collaboration is also motivated by the need to increase access to funds (Beaver, 2001; Heinze & Kuhlmann, 2008); to increase research productivity (Lee & Bozeman, 2005; Sooryamoorthy et al., 2007; Sooryamoorthy & Shrum, 2007); and to improve visibility and recognition (Narin et al., 1991).

Structural or macro-level factors that motivate research collaboration include the increased costs of conducting scientific research; for instance, the construction of large laboratory facilities and the purchase of expensive research equipment. Such costs call for the pooling of resources, hence collaboration is deemed to increase efficiency in the production of science (De Solla Price, 1963; Katz & Martin, 1997). Other such factors include the increased need for specialisation within scientific fields (Beaver, 2001; De Solla Price, 1963; Goffman & Warren, 1980; Katz & Martin, 1997; Maanten, 1970; Thorsteinsdottir, 2000); the growing interdisciplinary research in fields like biotechnology (Katz & Martin, 1997; Ponds, 2009); cross-fertilisation across disciplines (Beaver 2001; Katz & Martin, 1997); as well as political factors (Katz & Martin, 1997; Sonnenwald, 2007).

Using questionnaires, Bozeman and Corley (2004) conducted a study to investigate the factors considered by researchers when choosing collaborators. They used a factor analysis to identify six underlying factors considered when choosing collaborators. The authors assigned the following terms and descriptions to the factors: (i) taskmasters, those who select their partners based on their reliability and work ethics; (ii) the nationalists, those who choose collaborators who are fluent in their own language and are of the same nationality; (iii) the follower, those who choose collaborators mostly because someone in administration requested that they work with the collaborator and the potential collaboration has a strong science reputation; (iv) the buddy, those who choose collaborators based on the length of time they have known the person, the quality of previous collaborations, and whether or not the collaborator is fun and entertaining; (v) the mentors, those who are motivated to help junior colleagues and graduate students by collaborating with them; and (vi) tacticians, those who choose collaborators based on whether or not the collaborator has skills complementary to their own.

Sargent and Waters (2004) categorised the reasons for collaboration into instrumental and intrinsic factors. Instrumental factors relate to resource-based rationales such as access to resources and special equipment, while intrinsic factors refer to individual choices and preferences such as knowledge-based rationales, including access to diversified skills and expertise, boosting productivity, and personal gains (ibid.). The extent to which instrumental and intrinsic reasons influence collaboration decisions varies based on the existing conditions within research environments. With the majority of research systems in developing countries constrained by limited resources (Gaillard & Tullberg, 2001; Harle 2010), the liberty of choosing which collaborations to enter into may be limited. In a more recent study, Stvilia et al. (2017) used questionnaires and interviews to identify which factors affect researchers' willingness to collaborate. The study identified personality, resources, costs, reputation, affiliation and cultural factors as motivating factors (see Table 4.2). Of these factors, the personality, followed by resources and cost scales, had the highest average importance score. The culture scale had the lowest average importance score. What these results indicate is that personality factors, such as the quality of research ideas and satisfaction from a past collaboration, and resource factors, such as complementary knowledge and skills, were important factors in the choice of collaborators.

Table 4.2: Mean importance scores for motivating factors in collaboration scale

Motivating factors	**Mean rating**
Personality	5.62
Satisfaction from past collaboration	
Researcher's personality	
Researcher has interesting research ideas	
Researcher has similar or different interests	
Resources	5.16
Researcher has complementary or similar knowledge	
Researcher has complementary or similar skills	
Researcher has or lacks access to important resources	
Costs	4.33
Possible effect of researcher's decision on their standing in the community	
Possible effect of researcher's decision on their standing in the organisation	
Researcher's availability or lack of resources for a new project	
Reputation	3.97
Researcher's seniority level	
Researcher's research reputation	
Reputation of researcher's home institution	
Affiliation	3.35
Researcher is from the same or different organisation	
Researchers is from the same or different academic disciplines	
Researcher's community affiliation	
Culture	1.53
Researcher has a similar or different cultural background	
Researcher belongs to the same or a different sex	

Source: Stvilia et al. (2017).

Stvilia et al. (ibid.) argued that these six motivating factors could be grouped into intrinsic and extrinsic motivations that might affect a researcher's decision to collaborate with another researcher. Intrinsic motivations are autonomous and self-determined because a researcher finds an activity they perform to be interesting or pleasant. Extrinsic motivations are induced externally through rewards or punishments. The reasons grouped under the personality factors can be considered intrinsic motivations while reasons grouped under resources and costs factors can be considered extrinsic motivations.

Pouris (2017) points to the fact that every country has different motivations for collaboration based on the perceived potentials and anticipated developments in science and technology. Iglic et al. (2017) also report that factors explaining international collaboration differ from those accounting for domestic collaboration. They argue that in small science systems, international collaboration allows researchers to specialise and connect with partners holding complementary knowledge not available inside the country. It also allows scientists from smaller and less central science systems to connect with global knowledge production centres and with more prominent researchers. On the other hand, in the domestic arena, the primary distinction is between intra- and inter-organisational collaboration. Inter-organisational collaboration is considered a vehicle for resource mobilisation. Researchers turn to colleagues in other organisations to gain access to additional resources and to apply jointly for research funds from national research agencies. By contrast, intra-organisational collaboration relates to the elaborated division of labour, especially in laboratories and highly competitive research environments (ibid.).

Having discussed the factors that motive research collaboration, the next section focuses on how collaborator attributes affect collaborators' willingness to engage in research collaboration.

4.6 How collaborator attributes influence willingness to collaborate

The framework for the research collaboration literature proposed by Bozeman et al. (2013) highlights three main attribute categories frequently analysed in the literature; namely, literature relating to collaborator attributes, attributes about the collaboration process in general, and specific organisational or institutional attributes. The collaborator attributes are subcategorised into three main attributes: (i) personal (i.e. gender, age, race, nationality), (ii) human capital (i.e. degree, field of training, work experience), and (iii) career (i.e. career stage). Studies in the literature have shown that the willingness to collaborate with others is largely influenced by these attributes.

Bozeman et al. (ibid.) identified gender as a key personal collaborator attribute in science. They highlighted that inasmuch as the influencing factors of female collaboration can be defined as the scientists' career attributes, "the outcome of female collaboration is highly personal" (ibid., p. 8). Several studies in the literature show gender differences in relation to reasons of collaboration and with whom to collaborate. Studies by Bozeman and Corley (2004) and Sonnert and Holton (1996), among others, highlight that women scientists collaborate less than their male colleagues. Women scientists are also more likely to establish more formal collaborations than their male counterparts. In their study, Bozeman and Corley (2004) found that female scientists have a somewhat higher percentage (36%) of female collaborators, than males have (24%). However, when it comes to rank, non-tenured women have 84% of their collaborations with other women. By contrast, only 34% of women's collaborations are with other women. This might suggest that as women climb the scientific career ladder, they become less concerned about demographic characteristics such as gender. Bozeman and Gaughan (2011) found that men and women faculty researchers differ significantly in their strategies for choosing collaborators. That is, men are more likely to tend towards collaborations based on instrumentality – that is, those concerned with immediate works factors, including assignment of credit – and previous experiences, compared to women. On the contrary, Stvilia et al. (2017) argued that regardless of gender, researchers with more experience and more high-level research roles (i.e. principal investigators) care more about the quality of ideas and the personality of a collaborator and less about social characteristics of the collaborator, such as their sex or culture.

Stvilia et al. (ibid.) categorise personal characteristics into two types: surface level – demographic characteristics that are easily observable, such as age, sex, or race; and deep level – less observable psychological characteristics such as personality, values and attitudes. If individuals are interdependent in achieving a common goal, their impressions of each other are more nuanced, more focused on individual personalities, and less influenced by social categories such as age, race and sex (ibid.). In addition, as the history of collaboration among members of a team lengthens, the effects of perceived surface-level differences on the team's social integration are more likely to lessen and the effects of deep-level characteristics are more likely to increase. Therefore, it is expected that researchers with more experience with collaboration and the management of collaborative projects are likely to pay more attention to a potential collaborator's personality and less attention to the collaborator's surface-level characteristics, compared to young researchers who have not had that level of collaboration experience (ibid.).

The career stage of an individual is likely to influence their collaboration choices. Stvilia et at. (ibid.) argue that senior researchers, who have already established themselves in their careers, care less about the possible costs of their collaboration decisions on their standing in the organisation or community, compared to junior researchers who are just starting their careers. Tsai et al. (2016) note that junior researchers do not choose to collaborate, rather they are expected (required) to do so and are thus usually less independent in their decisions about collaborations. They work under the supervision of senior researchers and, in most cases, might not be able to decline a collaboration offer from their senior without incurring a negative impact on their work status. In this regard, being in the early stages of their careers and not having similar levels of job security as older, more experienced researchers do, younger researchers might have to be strategic in choosing collaborations that are less risky and that will help advance their careers in a predictive way (Stvilia et al., 2017).

4.7 Research collaboration processes and composition

In this section, the focus shifts to research collaboration processes and composition; in other words, the second category in the framework used by Bozeman et al. (2013) to organise the discussion of the research collaboration literature. Several scholars have examined research collaboration processes and composition. Most of these, as indicated earlier, assessed how the attributes of collaborative groups interact and affect collaboration activities and outcomes. This section highlights various models and frameworks that have been used or proposed to understand the research collaboration process. It also discusses how different attributes affect collaboration activities and outcomes.

A scientific collaboration goes through various stages from its inception to its conclusion. Several models have been developed to explain the collaboration process. Some of these have focused on the identification of stages and tasks associated with each phase of collaboration (e.g. those by Kraut et al., 1987; Sargent & Waters, 2004; Sonnenwald, 2007). Others have focused on factors that influence the accomplishment of collaboration tasks (e.g. those by Amabile et al., 2001; Bozeman et al., 2016; Maglaughlin & Sonnenwald, 2005; Stokols et al., 2008), while yet others focus on the decision-making processes during the collaboration process (e.g. Vaseleidiadou, 2009). Discussed first below are those scholars who identified the stages and tasks associated with each phase of collaboration.

Drawing on empirical data involving 50 interviews across three disciplines, Kraut et al. (1987) identified and described three stages through which research collaborations progress; namely, initiation, execution and public presentation. Kraut and colleagues argued that at each stage, activity takes place at two levels – the relationship level and the task level. In the initiation stage, potential collaborators establish personal relationships, commit themselves to working together, and plan projects. The main goal in this stage is to establish interpersonal relationships based on shared interests. External environmental factors such as access to resources, physical proximity and institutional factors are integral in establishing relationships. In the execution stage, the actual work is carried out. The challenge in this stage is usually how to develop equitable division of labour and procedures for managing the work effectively. In the public presentation stage, researchers document and disseminate their research. In this stage, collaborators evaluate each other's work and make decisions about the order of authorship and the responsibility for public talks (ibid.).

Sargent and Waters (2004) identified phases in the lifetime of a collaborative research project and highlighted the factors that affect the processes at each phase. According to them, contextual factors play an important role in shaping collaboration processes. They argue that collaborations do not occur in isolation from the broader professoriate community, and that these communities are thus integral to success of collaborations. Drawing on data from a two-stage empirical study involving career researchers, Sargent and Waters developed a process framework that identified four main collaboration phases: initiation, clarification, implementation, and completion. The framework identified both contextual factors (resources, institutional support, climate) and interpersonal processes (trust, communication, attraction) affecting collaborative research. They also identified the institutional climate shaping the nature of collaborations as including institutional processes and strategies, and differences across universities (e.g. research-oriented vs. teaching-oriented). Inclusion of people from different national settings captures collaboration experiences across different contexts or environments in which collaborations occur, which could influence the processes (ibid.).

Sonnenwald (2007) analysed literature on the various aspects of scientific collaboration and developed a framework that identified the phases of collaboration and the factors influencing the processes within each phase. Sonnenwald identified four stages through which the research collaboration process takes place. The first stage is the foundation stage, which is concerned with conditions that lead to initiation of a collaboration or the motivation for collaboration. These are grouped into five factors: scientific factors, such as the need to gain access to resources, knowledge and expertise; political factors, such as promoting unity in regions; socio-economic factors, given the importance attached to the link between research and economic development; and social network and personal factors, such as ideas springing up as a result of ties within one's personal networks. The second stage is the formulation stage. During this stage, researchers come together to prepare and plan the research work.

This stage is concerned with factors that affect project planning, such as diverse disciplinary, institutional and organisational cultures. Sonnenwald noted the negative effects of distance on formation and performance of collaboration processes. The third phase, the sustainment stage of collaboration, is maintained to reach set goals. This stage deals with emerging challenges, including changes in administration and relevant policies (also noted in Katz & Martin, 1997); access to resources; communication and coordination; and personal differences. Finally, in the conclusion stage, research results are realised and disseminated. During this phase, problems associated with the dissemination of results – such as disagreement on publication forum, authorship conclusion and order of authorship names – are addressed. Sonnenwald’s analysis brings out both internal factors related to actual performance of tasks, and external factors that may influence the initiation of a collaboration and the processes that follow.

What can be learnt from this section is that a collaboration goes through different stages. These stages (i.e. from the initiation where relationships are drawn based on shared and personal issues, to the execution stage where research work is done and roles are allocated, and then to the decision-making stage) are equally important and have an impact on collaboration outcomes. The stages can overlap with each other as decisions are made throughout the cycle of a collaboration. The next section discusses how the attributes of collaborative groups interact and affect collaboration activities and outcomes.

4.8 Factors affecting the collaboration process

The focus shifts to the factors that affect research collaboration. Presented in this section are the factors that affect collaboration based on locus of control (i.e. internal and external locus of control). This is followed by a presentation on the factors that affect collaboration based on a model of research collaboration effectiveness (i.e. proposed by Bozeman et al., 2013).

4.8.1 Factors that affect research collaboration based on locus of control

Several factors influence the formation, process and structure of research collaboration. These factors can be grouped into two broad categories; namely, internal and external factors. Internal factors relate to the research characteristics and the role of the individual in the conduct of collaboration tasks. These factors are usually within control of the collaborator. External factors relate to research environment conditions that a collaborator may not have direct control over, but which may shape their conduct, behaviour and the collaboration process. Table 4.3. provides an illustration of factors that affect collaboration based on internal and external locus of control.

Table 4.3: Factors that affect research collaboration based on locus of control

Factors	Source
Factors related to internal locus of control	
Motivation for collaboration – work dependency (skills and expertise, labour efficiency), personal gains (visibility, recognition, productivity, intellectual companionship), resource dependency (funding, special equipment)	Beaver (2001); Bozeman & Lee (2005); Katz & Martin (1997); Melin (2000); Sooryamoorthy & Shrum (2007); Sooryamoorthy (2013)
Personal characteristics – trust, ethical issues, transparency, personal expectations, beliefs and individual goals, skills and capability, commitment and readiness to collaborate	Amabile et al. (2001); Beaver (2001); Cummings & Keisler (2005); Maglaughlin & Sonnenwald (2005); Sonnenwald (2007)
Personal networks, prior collaboration experiences	Cumming & Keisler (2005); Sonnenwald (2007); Maglaughlin & Sonnenwald (2005); Ynalvez & Shrum (2011)
Process management factors – communication and coordination mechanisms, including the use of ICTs; nature of the work; task interdependency; leadership structures; conflict resolution mechanisms; agreements on quality; intellectual property rights; information security; scientific competition; and commercialisation	Cummings & Keisler (2005); Ynalvez & Shrum (2011); Vasileiadou (2009); Kraut et al. (1987)
Factors related to external locus of control	
Resource availability – funding, special equipment	Beaver (2001); Heinze & Kuhlmann (2008)
Institutional cultures and support structures – provision of resources, institutional norms and procedures, processes for information flow, reward mechanisms	Bozeman & Corley (2004); Sonnenwald (2007); Sooryamoorthy (2013)
National research environment, policies and political situations	Sonnenwald (2007)
Distance and spatial proximity	Katz & Martin (1997); Kraut et al. (1987)

Source: Author's compilation

As already discussed in Section 4.3, a number of factors motivate researchers to engage in research collaboration. Without these motivating factors, research collaboration would seldom occur. Hence, motivating factors are identified firstly as internal factors that affect the collaboration process. Several scholars have written extensively about how the collaboration is affected especially by personal characteristics such as skills and capabilities, commitment and readiness to collaborate, trust, ethical issues, transparency, personal expectations, beliefs and individual goals, as well as prior collaboration experiences. For example, commenting on the issue of trust, Bozeman et al. (2016) argued that researchers have strong preferences to focus most of their collaborative work on those with whom they have had previous collaborative successes, rather than developing the broadest possible collaborative network. This prior connection creates a feeling of solidarity in partnerships, underlining the target of collective goals. The role of experience in collaborations, according to Bozeman et al. (2016), is closely linked to trust – partners, individuals and institutions who know each other always strike accords in collaborations. Collaboration can also lead to negative outcomes for researchers and, for this reason, researchers tend to choose to work with collaborators they trust (ibid.).

Several structural hurdles (i.e. external in nature) determine the success or failure of collaboration, especially between researchers from developed and developing countries. For instance, it is common knowledge that the cost of collaboration is at a premium for researchers in many developing countries (except for a few prestigious institutions within them), in contrast to those in developed countries (Sooryamoorthy, 2013). This is the case because basic essentials for conducting research (e.g. phone calls, postage, the Internet, email, stationery, printing and copying, library searches, databases, assistance local travel, equipment and laboratory material) are not always at the disposal of researchers in poorer countries. Both Styilia et al. (2017) and Sooryamoorthy (2013) argue that researchers have to be wary of the costs and benefits of research collaboration. Costs are incurred in terms of administration, coordination, travel, communication, occasional face-to-face meetings, and the real work of the partners. Some of the benefits are access to equipment, knowledge, skills, expertise, interaction, publication and citation. Collaboration requires a great many prerequisites for its initiation, execution and successful conclusion (Sooryamoorthy 2013).

Varied views are provided in the literature about the role of geographic proximity in collaborations. While some authors (e.g. Stefaniak, 2001; Van Raan, 1998; Wagner & Leydesdorff, 2005) argue that close spatial proximity encourages collaboration because of more opportunities for informal networking, other studies argue that geographical proximity serves only an indirect role in collaboration (e.g. Boschma, 2005). For instance, some scholars in developing (peripheral) countries strategically choose to collaborate more with scholars in developed (core) countries, than with their regional counterparts, in order to access advanced knowledge and funding opportunities (Kim, 2006; Schubert & Sooryamoorthy, 2010). A clear case is that of South Africa. The country's top three collaborating partners are the US, UK and Germany, and the only African country among its top 20 partners is Nigeria, which is not in close proximity (Schubert & Sooryamoorthy, 2010).

4.8.2 Factors affecting research collaboration based on a model of research collaboration effectiveness

Collaboration is not always a positive experience and it can often lead to a negative outcome for scholars (Bozeman et al., 2013). Based on previous studies, and in particular the results of a qualitative study carried out to investigate good and bad collaboration experiences of researchers, Bozeman et al. (2016) developed a model of research collaboration effectiveness. The model comprises four main categories: external factors, team characteristics, individual team members, and team management designed. These categories are subcategorised into attributes that determine research collaboration effectiveness (see Figure 4.3). The model concerns itself with the concepts and determinants of research collaboration effectiveness. It can be used to identify factors that researchers view as integral during the collaboration process.

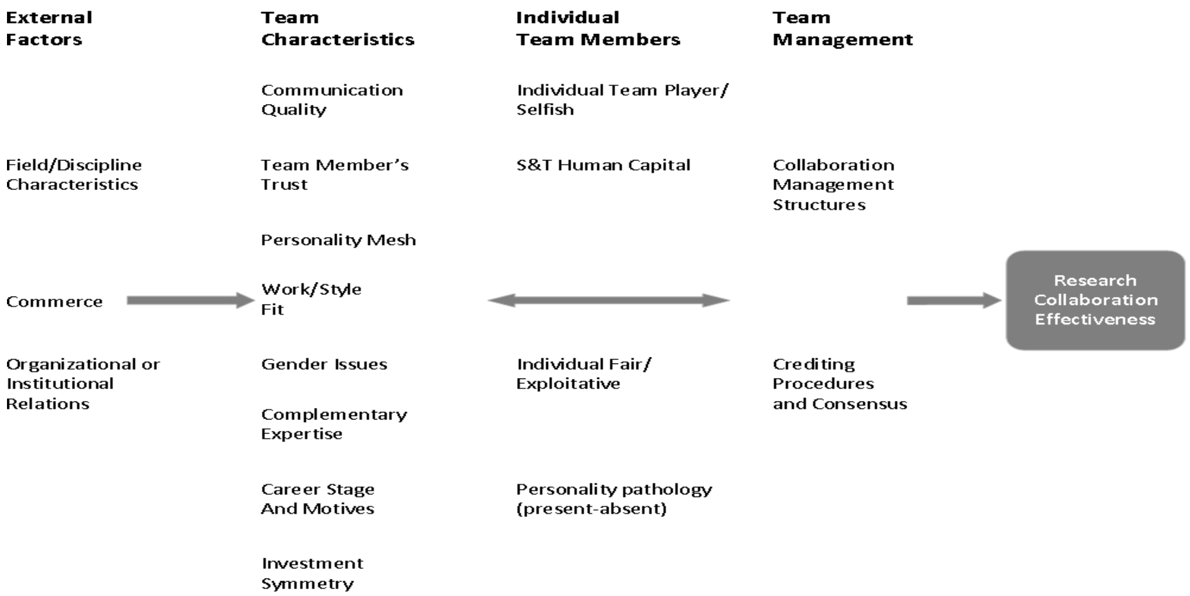

Figure 4.3: Model of research collaboration effectiveness

Source: Bozeman et al. (2016)

4.8.2.1.External factors

The first category in the model consists of three main attributes: (i) field/disciplinary characteristics, (ii) commerce, and (iii) organisational/institutional relations. Several studies have revealed that collaboration levels and co-authorships vary across scientific fields or disciplines (e.g. Katz & Martin, 1997; Lee & Bozeman, 2005; Lewis et al., 2012). Melin (2000), for example, noted that the readiness to collaborate as well as the forms under which collaboration occurs, vary between different scientific disciplines. He showed that scientists in the medical sciences engaged in collaborative research more than those in the humanities. Similarity, Lee and Bozeman (2005) showed that scientists in theoretical fields collaborate less and have lower productivity levels compared to those in experimentally intensive or applied fields. They found that scientists in the field of engineering collaborated more compared to those in biology and life sciences.

Different disciplines might have different inclinations for interdisciplinary collaboration (Stvilia et al., 2017). In their study, Van Rijnsosoever and Hessels (2011) found that researchers from fields dominated by basic research (i.e. mathematics) engaged in fewer interdisciplinary collaborations compared to those from applied disciplines (i.e. medicine). Given these disciplinary differences, Haythornthwaite (2006) argued that successful interdisciplinary collaborations require attention to invisible practices. Star and Strauss (1999) remarked that differences in team members' knowledge, practices and physical locations based on their institutional associations, their disciplinary ties, and their cultural outlook, must be bridged to facilitate and increase data, information and knowledge-sharing. Such bridging requires learning about others' fields and practices and developing new practices (Haythornthwaite, 2006, p. 763).

Regarding organisational relations, Stokols et al. (2008) identified five organisational attributes that affect collaborative effectiveness of interdisciplinary research: (i) presence of strong organisational incentives to support collaborative team work; (ii) non-hierarchic organisational structures to facilitate team autonomy and participatory goal-setting; (iii) breadth of disciplinary perspectives represented within the collaborative team or organisation; (iv) organisational climate of sharing (e.g. sharing of information, credit, and decision-making responsibilities is encouraged; and (v) frequent scheduling of social events, retreats and other centre-wide opportunities for face-to-face communication and informal information exchange. Institutional relations also play a role. In addition, Harle (2010) noted that good institutional policy environments and cultures of management which create the conditions and sets rules and procedures which, in turn, enable research to take place, determine the success of collaborations. Melin (2000), in an earlier study also raised the same point, noting that research policies should create systems for social interaction and networking of scientists. It is during these informal social interactions that interpersonal relations are created.

Commercial applications can have an impact on research collaboration effectiveness. Generally, practitioners and researchers have different norms, values and cultures. While researchers are interested in the theoretical aspects of a research study, practitioners are only interested in the results. These differences have an effect on the collaboration process. For example, Amabile et al. (2001) found that while practitioners wanted results disseminated as soon as they were available, academics – whose credit and recognition is to a large extent based on the quality of work and output – were keener on disseminating complete results. Amabile et al. (ibid.) explored the success factors of academic-practitioner collaborations. They classified determinants of successful collaborations into three categories. The first, collaboration team characteristics, focuses on personal factors related to the individual such as skills and knowledge, attitude and motivation. Collaborative team characteristics of particular importance appear to be: (i) project relevant skill and knowledge, (ii) collaboration skills, (iii) attitudes and motivation, and (iv) compatibility of problem-solving styles. The second, collaboration environment characteristics, focuses on support required for collaboration to succeed, mainly in form of institutional or organisational support. The third, collaboration processes and outcomes, focuses on issues of managing the process, including conflict resolution, task allocation and coordination, and dissemination of results. Amabile's framework encompasses both team characteristics and process-specific factors towards explaining the effects of the individuals' or group behaviour on the success of collaborations across sectors.

4.8.2.2 Team characteristics

The second category in the model developed by Bozeman et al. (2016), team characteristics include attributes such as communication quality, trust between team members, work fit, gender issues, career stage and motives, and complementary expertise. All these attributes can make or destroy collaboration efforts. In the model, Bozeman et al. show a two-way causal arrow between the characteristics of teams and aspects team members, owing to the dynamic relation between the two. Although these two constructs are more or less the same, Bozeman et al. state that often in teams it is the fit of the particular skills and preferences and values that are most important. In any team, effectiveness is a matter not only of the components of the team but the unique relationships among those components and, thus, team characteristics flow from this fit, not just from aggregated attributes (ibid.). Bozeman and colleagues identified some bad collaboration experiences likely to be faced by individuals in research teams. These include (i) disagreements about authorship credit; (ii) individuals insisting on authorship but having made no contribution; (iii) being exploited by others; (iv) conflicts arising from differential levels of investment in collaboration; (v) conflicting norms, rules and expectations of the participants' respective organisations; (vi) conflicting norms and expectations of people from different nations; (vii) collaborators seeking undue and unhelpful levels of control of the collaboration or collaborator; and (viii) friction owing to diverse personality types and individuals failing to meet deadlines.

Stokols et al. (2008) identified some interpersonal attributes of research teams that positively affect collaborative effectiveness of interdisciplinary research. These include (i) members' familiarity, informality and social cohesiveness; (ii) diversity of member's perspectives; (iii) ability of members to adapt flexibility to changing task requirements and environmental demands; (iv) regular and effective communication among members to develop common ground and consensus about shared goals; and (v) establishment of a hospitable conversational space through mutual respect among team members. Stvilia et al. (2017) found that researcher's personalities, including their credibility and generosity were critical to collaboration success. They argued that the quality of team members and the prevention or successful resolution of conflicts impact the quality and success of a collaborative project.

4.8.2.3 Individual team members

The third category, individual team members include individual team player/selfishness, scientific and technical (S&T) human capital, individual fair/exploitative and personality pathology. Personality problems, rampant egomania, and selfishness are all inter-collaborator factors that can lead to poor collaborations. Attributes that can make research collaboration a success, as proposed by Stokols et al. (2008) include (i) members' attitudes toward collaboration and their willingness to devote substantial time and effort to transdiciplinary activities; (ii) member's preparation for the complexities and tensions inherent in transdisciplinary collaboration; and (iii) participatroy, inclusive and empowering leadership styles.

4.8.2.4 Team management

The last category in the model is team management. Katz and Martin (1997) state that as teams continue to grow in size, diversity and dispersion, effort is required to manage the research. When the collaboration spans disciplines and nations, formal management procedures and structures might be required. The basics for good management, as observed by Bozeman et al. (2016), include frequent and effective collaboration, respect for others' ideas and needs, and recognising diverse disciplinary fields. It could be argued that where two or more institutions collaborate, there are often problems of reconciling different management cultures, financial systems, and rules on intellectual property rights. There may also be differences over reward systems, promotion criteria and time-scales, and even a more general clash of values over what is the most important research to pursue, how to carry it out, or over commercial or ethical implications. All these potential differences need to be reconciled if serious problems are not to disrupt the collaboration (Katz & Martin, 1997). The section that follows provides a detailed discussion on article authorship disputes.

4.9 Article authorship disputes

As already mentioned in the previous section, where two or more individuals collaborate, conflicts can occur. Conflicts arise owing to diverse disciplinary backgrounds, cultures, and differences in perspectives and working styles. (Hara et al., 2003; Katz & Martin 1997; Youtie & Bozeman, 2016). Conflicts can be between individuals; within or between groups, departments and institutions; or with project management. Youtie and Bozeman (2014) note that 80% of respondents in a study they conducted had had to deal with authorship disputes at some point in their career. Faulkes (2018) weighs in on the figures as he notes that studies conducted on the prominence of authorship disputes show that between a third and two thirds of researchers have been involved in authorship wrangles. Scholars are in agreement that collaborative authorship brings with it problems inasmuch as it is of benefit to the parties involved. The contribution of more than one person to an article is a breeding ground for disputes that ensue in academic research and article authorship (Faulkes, 2018; Zutshi et al., 2012).

There are no clear stipulations about who should be an author, who contributes what, and who gets credit for the work done (Faulkes, 2018). A few stipulations available are at the journal level; for example, the standard classification of collaborators widely used in scientific research was drawn up by the International Committee of Medical Journal Editors (ICMJE), commonly referred to as the Vancouver Group. According to the Vancouver group cited in Faulkes (ibid.), the researcher who contributes the largest portion of work and writing is the first or principal author and deserves the most credit. The last author in terms of credits, according to Faulkes (ibid.), is the individual who was not directly involved in data gathering, but supplied key intellectual questions, writing and funding. However, despite having the standard ICMJE model there have been some article disputes. This is because conflicts emanate at the individual level. Journals do not always have control over what happens during the writing process. The next section discusses the causes of article authorship disputes and how these disputes vary across fields, career stages and team sizes.

4.9.1 Causes of co-authorship disputes

Authorship irregularities are, among other factors as a result of the misuse of seniority to gain authorship credit, and the desire to gain credit without being part of the collaboration process (Bennett & Taylor, 2003). Other issues arise when co-authors fail to meet commitments and deadlines. Zutshi et al. (2012) argue that disputes usually arise from author attribution; that is, who is to be credited for the work done. They posit that despite having some guidelines, which already exist in medicine and sciences as promulgated by research committees and certain journals, disputes about attribution are still a major occurrence when it comes to co-authorship. The challenges mainly arise from issues to do with "order of authorship, working with students, individual workloads and credit, opportunism and plagiarism, honorary authorship, and ghost authorship" (ibid., p. 6). Authors tend to give credit to researchers they think are more prestigious and whose names might add weight to the project (Baker et al., 2012). Other authors believe that some contributions are not worth attribution, while others insist that any form of contribution to research, including data gathering, warrants recognition in the form of co-authorship (Bozeman & Youtie, 2015).

Different disciplinary backgrounds also have the potential to precipitate authorship disputes. Duque et al. (2005) argue that co-authorship practices in different scientific fields are guided by different social norms. These differences may result in conflicts and misunderstandings, affecting interpersonal relationships. Scientists in different disciplinary fields may disagree on publication forums, formatting of papers, especially for interdisciplinary research or for authorship inclusion and order (Sonnenwald, 2007). Bozeman et al. (2016) showed that there are disciplinary differences in the order of article authorship. For example, fields such as mathematics and economics commonly use the alphabetical order of the last name to allocate article authorship positions. Laboratory-based disciplines such as biomedical sciences regard the last-author position to be the most important, whereas in some disciplines the last-author position is regarded as the least important. Multiple first authors are even accommodated in some fields such as biosciences through the use of an asterisk in the publication, whereas most fields only have singe first authors (Youtie & Bozeman, 2016).

The types of authorship disputes vary from one field to the other. Fields with high levels of collaboration (e.g. the health sciences) are more likely to experience authorship disputes as compared to those who collaborate less (e.g. mathematics). This explains why biomedical and health science scholars pay much more attention to unethical authorship practices than other disciplines do (Ross et al., 2008). In a review of the literature on authorship issues, Marusic et al. (2011) found that two thirds of studies of unethical authorship practices were from the fields of biomedical and health sciences, while only one third of the studies were from natural and health science fields. Tsai et al. (2016) also found that scientists in five different disciplines (i.e. life sciences, physical sciences, engineering, mathematics and economics) faced different authorship problems. For example, physics scholars were found to be more likely to have a co-author who did not finish agreed upon research, while researchers in engineering were more likely than others to have experiences of undeserved lead authorship. Additionally, mathematics and economics scholars were less likely than their peers to have experienced a co-author not receiving deserved credit on an article. These results were partially explained by the fact that scholars in mathematics and economics had fewer co-authors on their most recent article than their peers (ibid.).

Junior researchers are more likely to face authorship problems (i.e. contribution issues and unequal authorship credit decisions) compared to senior researchers. Bennett and Taylor (2003) argue that junior researchers may feel pressured to give senior researchers undeserved credit in order to get published easier, or to repay favours for funding and research opportunities. In addition, senior scholars often have the power to distort authorship credits. Kwok (2005) reports that senior researchers may abuse or bully junior scholars by distorting co-authorship credits or conducting deceptive behaviours. Also, as compared to senior researchers, junior cohorts face greater pressures in terms of getting tenure, promotion, resources and even academic prestige (Tsai et al., 2016). Junior researchers often end up getting opportunities to participate in co-authored articles at the expense of unfair treatment and negative experiences. To this end, Tsai et al. (ibid., p. 525) recommended that “rather than taking cohort differences for granted or simply assuming ‘it is the way it is’, university or department directors need to contemplate this problem and manage to create a friendly and fair collaboration environment for junior and next generation scholars.”

Literature also shows that younger researchers might be less involved than older researchers in decision-making related to collaborative projects, and that the process might remain non-transparent to them. Some senior researchers might not consider students working with them on joint projects as collaborators; rather, they might see themselves more as teachers than as collaborators. This causes tension either way. Disputes are also more likely to increase in large research projects spanning countries, as compared to small research teams located within the same locations (Tsai et al., 2016). As highlighted earlier by Katz and Martin (1997), with more people and perhaps several institutions involved, greater effort is required to manage the research. If the collaboration is large or spans a considerable distance, it might need more formal management procedures, which may create problems of bureaucracy.

Professional backgrounds and cultures can also be a source of conflict. As already discussed in the previous section, collaboration involving practitioners and universities are likely to face disputes owing to differences in norms, values and cultures. While researchers are interested in the theoretical aspects of a research, practitioners are only interested in the results. Presented in the next section are ways of mitigating and minimising disputes.

4.9.2 Mitigating and minimising co-authorship disputes

To mitigate or minimise authorship disputes, Mullen and Kochan (2001) prescribe working with researchers with whom one shares the same interests and have a rapport, and are free to openly address whatever issues might arise during the process. Bozeman and Youtie (2016) concur with this view adding that engaging in "enjoyable collaborations" makes co-authorship less likely to be marred by disputes. They cite different high-ranking professors who indicated that as they grew in their careers, they focused more on enjoyable collaborations and working with people they liked, as opposed to choosing collaborators on the basis of what they bring to the table. Adegbaye et al. (2017), state that researchers prefer to collaborate with people from the same institution or field as this makes the collaboration smooth.

Youtie and Bozeman (2016) identified a range of implicit and explicit approaches to resolving disputes. Explicit approaches include listing papers and authorships at the beginning of a project, or developing policies to specify authorship order or authorship considerations linked to disciplines involving large numbers of authors. Explicit approaches also include training students on how to handle authorship problems, or to specify authorship criteria for the laboratory or research group concerned. Implicit measures include avoidance of further collaborations with particularly troublesome investigators, including some scholars as authors who may not have made an intellectual contribution, or erring on the side of the student in awarding co-author credit. Other scholars have made similar suggestions. For instance, the Nature Research journals' authorship policy[22] points to the importance of training in the social and ethical aspects of collaborative research, including how to determine the authorship order on collaborative publications and the responsibilities associated with that authorship.

Some examples of explicit approaches to resolving authorship disputes are provided in the Centre of Publications Ethics (COPE) Report (Norman et al., 2020). COPE mentioned a case where a research paper appeared in Journal X which was written by Dr A and his team acknowledging Dr B as a contributor. Dr A and B had worked and published jointly in the past, but at some point there appeared to be a divergence in points of view on the interpretation of their work. Dr B wrote to the editor of the journal complaining that a substantive part of the paper submitted by Dr A originated from his work. The editor noted that this was an authorship dispute and pulled the article from the journal pending finalisation of talks between the warring

[22] Nature Research journals website: https://www.nature.com/nature-research/editorial-policies/authorship, accessed September 2020.

parties. In another anonymised case, the COPE report (ibid.) states that five researches submitted an academic paper to a certain journal. When it was published, the authors wrote to the editor asking that one of the individuals listed as a co-author should be removed as the person was never part of the research. In addition, the researchers asked the editor to substitute the name of the removed individual with that of another researcher. The editor contacted the person whose name had been requested to be removed and subsequently removed their name from the journal.

However, regarding implicit and explicit approaches, Youtie and Bozeman (2016) warned that these approaches were overly too simplistic. Problems that precipitate these approaches are mediated by several contingency factors; namely, the nature of the field – whether or not it is laboratory-oriented, the size of the research project, the location of the researchers in the same department or college or university, and the length of time the researchers have worked together. Contingency factors are apparent in certain approaches for resolving problems. For example, scholars who have worked together for a long time are likely to use implicit mechanisms to deal with authorship-positioning disputes, while those who are new collaborators, and in the same department, may explicitly turn to the department chair to resolve the problem. Large projects may establish explicit formal rules, hold meetings and require training to prevent authorship disputes, while small groups may deal with issues internally (ibid.).

Authorship negotiations can be undertaken in advance, during the project, or even at the end of the project after work has been completed (Stvilia et al., 2017; Youtie & Bozeman 2016). In their study of scientists in the field of physics, Stvilia et al. (2017) found that negotiating the order of publication authorship when writing a paper was frequently done by 84% of their participants. More than 30% reported negotiating the order of authorship when presenting findings, while the fewest (22%) indicated that they negotiated the order of authorship at the beginning of the project. Similarly, in their study, Youtie and Bozeman (2016) found that while some participants were able to be specified and dealt with in advance, particularly in disciplines involving large-scale research projects, others were inappropriate for advance measures because of the informal nature of the collaboration or because unpredicted problems emerged while the research was underway.

Despite the various approaches mentioned above, Youtie and Bozeman (2016) still warned of trade-offs. Trade-offs occur when one type of action creates a number of other problems. Some of the trade-offs identified by (Youtie & Bozeman 2016, p. 395) include:

- Deciding on direct confrontation, particularly with hostile people, may cause problems down the road, especially if the difficult collaborators are in senior positions in the same academic department or field;
- Avoiding collaborations with difficult people poses the risk that less creative work may result;
- Resolutions of contributorship problems through obtaining agreements in advance can be imagined to conflict with norms of fairness, interactive participation and the free flow of knowledge, and even the need for flexibility in the research process;
- The notion that every author listed on a paper put in some work may be at odds with the ability to resolve lack of or lesser contributorship; and
- Resolving problems by escalating them outside of the research group or laboratory to either journal editors, funding sponsors or university sponsors, has the potential to cause problems later on.

The discussion provided above illustrates that dealing with authorship disputes is quite challenging, as a resolution may cause more problems. What could actually work, as highlighted in the discussion, is the need for universities or department directors to contemplate problems and manage them to create friendly and fair collaborations.

4.10 Conclusion

The conclusions drawn from the chapter are summarised under the following headings:

4.10.1 Definition of research collaboration

Research collaboration does not have an exact definition. It has a fuzzy or ill-defined border. Collaboration can be categorised into six levels; namely, individuals, group, department, institution and sectors. Of the three main methods used to measure research collaboration (i.e. bibliometrics, surveys and interviews), the bibliometric method is commonly used. Although the method has its own limitations, it has several advantages, including that it is invariant and verifiable; practical for quantifying collaboration; viable for large samples; and is unobtrusive and non-reactive, meaning it does not affect the collaboration process. There is general consensus among researchers that research on research collaboration can benefit more from a combination of data collection methods whereby the weakness of one method can be compensated for by the strength of another.

4.10.2 Factors that influence collaborators' willingness to collaborate

There are intrinsic and extrinsic motivations that influence researchers' decisions to collaborate with other researchers. Intrinsic motivations are autonomous and self-determined because a researcher finds an activity they perform interesting or pleasant. Extrinsic motivations are externally induced through rewards or punishments. The willingness to collaborate with others is may be influenced by several collaborator attributes, such as science field, career stage, gender and age.

4.10.3 The collaboration process

During the collaboration process, researchers may have positive or negative experiences. Negative experiences may include disagreements about authorship credit; individuals insisting on authorship but having made no contribution; being exploited by others; conflicts arising from differential levels of investment in collaboration; and conflicting norms, rules and expectations of the participants' respective organisations.

4.10.4 Article authorship disputes

Where two or more individuals collaborate, conflicts are bound to happen. Conflicts arise owing to diverse disciplinary backgrounds, cultures, and differences in perspectives and working styles.

There are implicit and explicit approaches to dealing with authorship disputes. Explicit approaches include listing papers and authorships at the beginning of a project, or developing policies to specify authorship order or authorship considerations linked to disciplines involving large numbers of authors. Explicit approaches also include training students on how to handle authorship problems, or to specify authorship criteria for the laboratory or research group concerned. Implicit measures include avoidance of further collaborations with particular troublesome investigators, including some scholars as authors who may not have made an intellectual contribution, or erring on the side of the student in awarding co-author credit. These approaches, however, are mediated by several contingency factors (i.e. the nature of the field the size of the research project, the location of the researchers in the same department or college or university, and the length of time the researchers have worked together). In general, dealing with authorship disputes is quite challenging as a resolution may cause more problems. What could actually work, as highlighted in the discussion, is the need for universities or department directors to contemplate problems and manage them to create a friendly and fair collaborations.

CHAPTER 5

Research design, data sources and methods

5.1 Introduction

The research design of the study can best be described as a quantitative case study of research collaboration in Zimbabwe. The two quantitative methods employed to shed light on the specific case include a bibliometric analysis and a web survey. In the bibliometric analysis, covering the period 1980-2016, both articles and authors were used as the unit of analysis. The central focus was on research collaboration as reflected in the trends and patterns of co-authorship (article level), and the trends and patterns of collaborating authors (author level). While the bibliometric method was useful for profiling research collaboration in Zimbabwe, it did not capture the full range of social dynamics experienced by researchers. Hence, a web survey was conducted to explore other aspects and experiences of research collaboration in order to provide greater depth and context to the bibliometric analysis.

5.2 Research design

Yin (2014, p. 16) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon (the case) within its real-life context especially when boundaries between phenomenon and context are not clearly evident.” Yin states that a case study should be applied when (i) the focus of the research is to answer ‘how’ and ‘why’ questions, (ii) one cannot manipulate the behaviour of respondents in the research study, and (iii) when one wants to contextualise conditions because one believes that context is pertinent to the phenomenon under investigation. In the current study, context is crucial in the understanding of research collaboration in Zimbabwe. Real-life context is incorporated into the analysis through a socio-political timeframe that mirrors reality, and which was developed to study research production and research collaboration patterns over time. Additional real-life context is provided by soliciting from Zimbabwean researchers, through a survey, responses to various aspects of research collaboration.

Compared to other designs, a case study captures the complexity of a case, including relevant changes over time. It attends fully to contextual conditions, including those that potentially interact with the case (Yin, 2014). Hartley (1994) describes a case study as a detailed investigation, often with data collected over a period of time, of one or more organisations or groups within organisations, with a view to providing an analysis of the context and processes involved in the phenomenon under study. Similarly, Gerring (2004) notes that a case study is an intensive study of a single unit for the purpose of understanding a larger class of similar units. A unit connotes a spatially bounded phenomenon such as a nation-state, a system or a person, observed at a single point in time or over some delimited period of time. A case study is not a method, but a research strategy; in other words, it focuses on understanding the dynamics present within single settings (Hartley, 1994).

In undertaking case studies, different methods can be used in collecting and analysing data. These methods may either be quantitative, qualitative or a combination of both. The current study employed quantitative methods to collect and analyse data. Descriptive quantitative analyses were used to explore the relationships between variables. The purpose of descriptive quantitative research, as noted by Fraenkel and Wallen (2003), is to become familiar with a phenomenon, to gain new insight, and to formulate more specific research problems or phenomenon. The two quantitative methods (i.e. a bibliometric analysis and web survey) solicited information about the research output and the trends and patterns of research collaboration in Zimbabwe. Details of how the bibliometric method and the web survey were used to gather and analyse data are provided in the sections that follow.

5.3 Bibliometric method

Bibliometrics is a quantitative method concerned with measuring the output of science (Godin, 2006). Pritchard (1969, pp. 348-349) defined bibliometrics as the "application of mathematical and statistical methods to books and other means of communication." Some of these mediums of communication include e-books, e-journals, monographs, journals, dissertations, papers in serials, and periodicals (Glanzel, 2003). Bibliometrics involves the process of analysing and measuring citations, authorships, and publication patterns. Publications provide elements for measuring research production and include metadata such as the names of authors, institutional addresses, journal titles, references (citations), and concepts (keywords and keyword combination) (Van Raan, 2004). The two commonly used bibliographic databases, which contain the publication elements used in bibliometric research, are Scopus and the Web of Science (WoS). These databases, as highlighted in Chapter 1, are comprehensive, containing bibliographic records of all fields of science. Google Scholar is considered to be another bibliographic source. However, the use of the database as a bibliographic data source is quite challenging (see Chapter 3, Section 3.5.1.).

5.3.1 Advantages and disadvantages of bibliometrics

The literature identifies several advantages of bibliometrics, especially for studies about research collaboration. Subramanyan (1983) argues that collaboration cannot be easily measured by traditional methods such as surveys and observation. Rather, bibliometric methods offer convenient and non-reactive tools for studying research collaboration. Bibliometrics facilitates the investigation of the relationship between research collaboration and variables pertaining to the research problem and the research environment by applying statistical techniques (ibid.). Studies on research collaboration measure collaboration through bibliometric examinations of co-authored publications. Katz and Martin (1997, p. 3) identified several advantages of using co-authorship as a unit of measuring collaboration, namely:

- It is invariant and verifiable. Given access to the same dataset, other investigators would be able to produce the results.
- It is relatively inexpensive, given that it does not have data collection costs.
- It allows access to large databases of co-authorship records, and ease of measurement.
- It is a practical method for quantifying collaboration.
- It is viable for large samples.
- It is unobtrusive and non-reactive, meaning it does not affect the collaboration process.

Although co-authorship exhibits several advantages, the measure has several limitations. Katz and Martin (1997) and Bozeman et al. (2013) argue that collaboration and co-authorship are not synonymous. Collaboration does not always lead to co-authorship. Melin and Persson (1996, cited by Tsai et al., 2016) point out that co-authored articles are not the only output that research collaboration produces, and that co-authorship does not guarantee the existence of collaboration. Co-authorship does not capture the whole picture of collaboration activities; instead, it represents a specific type of collaboration with its roots mainly in the write-up process (Katz & Martin, 1997). Bibliometrics therefore cannot capture the full range of social dynamics involved in research collaborations. In addition, some of the non-tangible aspects of a collaborative piece of work cannot be quantified (ibid., p. 3). Bibliometric studies also rely on mainstream databases such as Scopus and WoS. These databases have been criticised for being biased in favour of journals from industrialised countries and towards topics in those countries.

Despite all the limitations associated with bibliometrics, it remains the best measure for understanding research collaboration (Bozeman et al., 2013; Subramanyam, 1983; Tsai et al., 2016). According to Tsai et al. (2016), co-authorship remains one of the primary measures of research collaboration within existing scholarly literature. Given this, bibliometrics was used in the study to understand research collaboration in Zimbabwe. The bibliometric data was supplemented with survey data. The next section discusses in detail how the bibliometric method was applied in the study.

5.3.2 Development of a consolidated database for a bibliometric analysis of research production and collaboration in Zimbabwe

A consolidated database for a bibliometric analysis of research production and collaboration in Zimbabwe was developed. Data for the bibliometric analysis were obtained from three bibliographic databases; namely, Scopus, WoS, and the National Research Database of Zimbabwe (NRDZ). Each of these data sources is described in brief below.

Scopus was selected as it is reported to be the largest database for multidisciplinary scientific literature, covering about 84% of its predecessor's (WoS) journal titles (Gavel & Iselid, 2008). According to Sugimoto and Lariviere (2018), as of December 2016, Scopus indexed more than 60 million records from across all disciplines. Some of these records constitute papers published in 23 000 journals, six million conference proceeding papers, and approximately 130 000 books. Scopus hosts information on the addresses of authors, their institutions and country affiliation. This information makes it possible for one to identify collaboration patterns between institutions and countries, and patterns between individuals. Scopus is regarded as a high quality data source for contemporary analysis. Although it has some records dating back to the 1820s, consistent indexing has taken place from 1996 onwards (ibid.). Scopus is presumed to be of inferior quality compared to WoS when it comes to historical analysis (ibid.). Hence, in a bid to achieve a high coverage of journal articles (i.e. historical and contemporary) for the current study, both Scopus and WoS were used as the two main data sources.

WoS is considered to be the gold standard for bibliometric studies (Thompson & Walker, 2015). Sugimoto and Lariviere (2018) note that as of December 2016, WoS had a total of approximately 55 million documents and 1.1 billion reference links going back to 1900. Over that period, it covers papers published in about 12 700 journals, 160 000 conference proceedings, and 68 000 books. WoS is considered to be 'comprehensive' when it comes to the disciplines it covers. It has been consistent in its indexing practices since 1980. WoS hosts information on addresses of authors, their institutions, and country affiliations. This metadata facilitates collaboration analysis at different levels of aggregation (i.e. institutions and countries). WoS has been criticised for bias in its coverage, with researchers noting disparities in terms of journals, fields, geography, and language of what is referenced. It is reported that the coverage of the natural and medical sciences is higher than that of the social sciences, and that arts and humanities have the lowest coverage (Sugimoto and Lariviere 2018). WoS has also been criticised for having a bias in favour of journals from industrialised countries and towards topics in those countries (Ràfols et al., 2016).

The National Research Database of Zimbabwe (NRDZ) was used in this study in order to reflect on the added value of using a national research database as a bibliometric data source. The NRDZ is described on the Research Council of Zimbabwe (RCZ) website as "an online integrated and comprehensive 'one stop shop' covering all public domain research" in the country.[23] The database was created in 2010 by the RCZ and subsequently launched as a searchable database in December 2011. All Zimbabwean researchers and members of RCZ staff are eligible to deposit publications in the NRDZ. It has scripts that harvest publications from institutional repositories in the country. As of March 2019 the database had 3 113 records classified as articles, 1 869 records classified as dissertations, 34 books, eight conference papers, and two records classified as monographs.[24]

The three sources (i.e. Scopus, WoS and the NRDZ) were combined to generate a new and integrated database in Microsoft Access, consisting of variables with standardised labels and entries. Figure 5.1 shows the 14 steps taken to develop the consolidated database for a bibliometric analysis of research production and collaboration in Zimbabwe. The consolidated database had three variants:

- Article-level database 1: a main database of 10 753 unique Scopus and WoS articles in the period 1980-2016 (step 5 in Figure 5.1, green shaded)
- Article-level database 2: a subset of article-level database 1, consisting of 2 935 unique Scopus, WoS and NRDZ articles in the period 2012-2016 (step 8 in Figure 5.1, yellow shaded)
- Author-level database: a database of 11 606 unique authors of Scopus and WoS articles in the period 2009-2016 (step 14 in Figure 5.1, blue shaded)

[23] Research Council of Zimbabwe website: www.rc.ac.zw, accessed June 2019.
[24] Research Council of Zimbabwe website: www.rc.ac.zw, accessed June 2019.

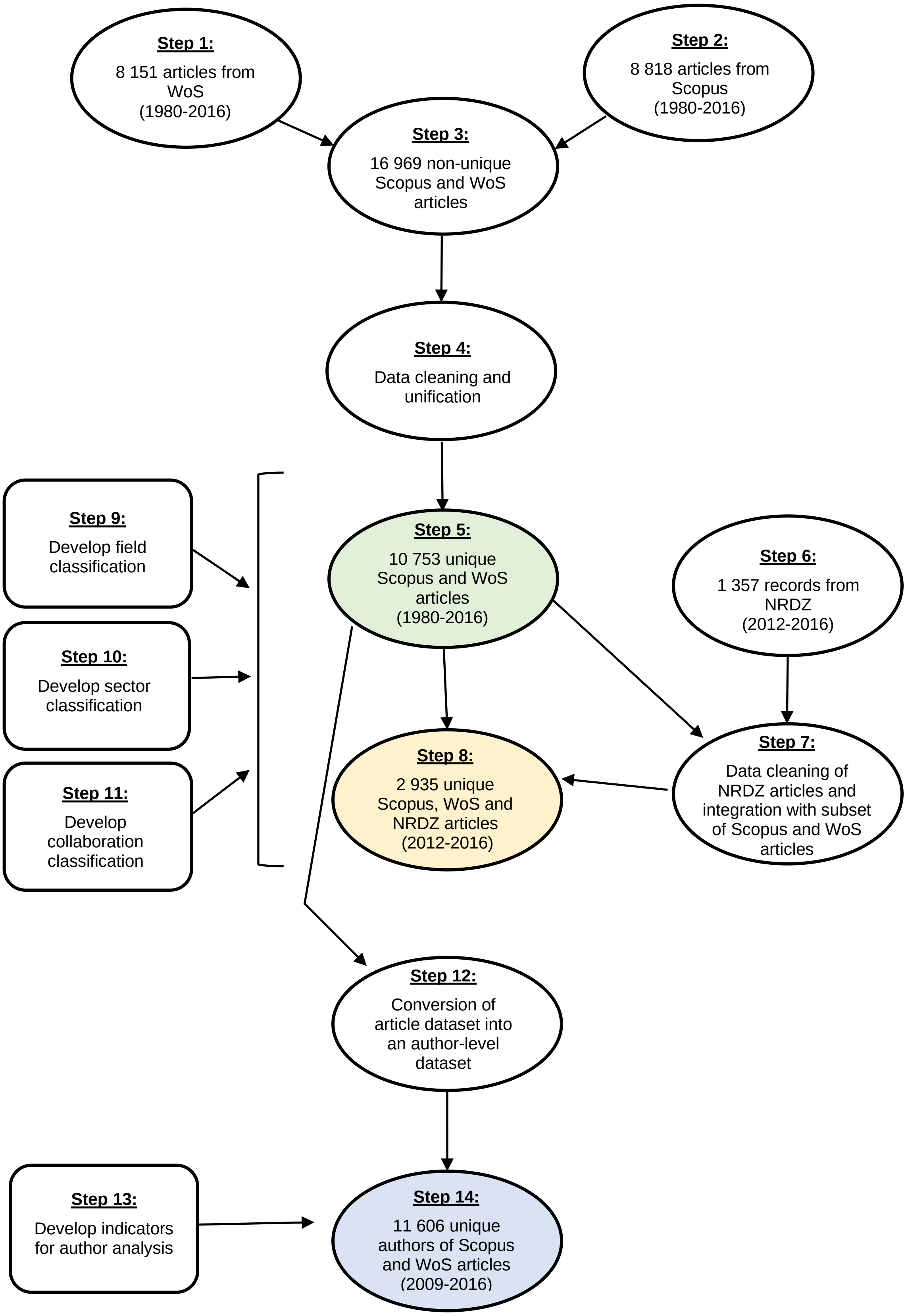

Figure 5. 1: 14 steps taken to develop the consolidated database for a bibliometric analysis of research production and collaboration in Zimbabwe

Step 1: WoS data

The first step entailed extracting WoS data from the database system at the Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University in South Africa. The Centre has access to WoS raw data in the WoS Core Collection database under an agreement with Clarivate Analytics. All documents of the 'article type', with at least one Zimbabwean author address and covering the period 1980-2016, were selected. The date of extraction was 2 February 2018. A total of 8 151 articles were obtained in three sets of tables. The first table contained key information about articles; namely, article ID, publication year, document type, source type, title, name of journal, and abstract. Each article and its details appeared in a separate row. Table 5.1 illustrates key information contained in the article data table.

Table 5. 1: WoS article data table

Article ID	Publication year	Document type	Source type	Title	Journal	Abstract
WOS:000071022400006	1997	Article	Journal	The recovery of ferrochrome from Slag at Zimasco	*Minerals Engineering*	Xyz …
WOS:000071059700004	1997	Article	Journal	Preliminary studies on relocation of Cape pangolins Manis temminckii	*South African Journal of Wildlife Research*	Xyz …
WOS:000277860700013	2010	Article	Journal	Farmer evaluation of phosphorus fertilizer application to annual legumes in Chisepo, central Malawi	*African Journal of Agricultural Research*	Xyz …

The second table contained details about article authors; namely, article ID, publication year, author's name, author's email address(es), author's organisation, and author's country. All these details could be linked back to the first table based on the article ID. Each author's name and his or her affiliation appeared in a separate row. Table 5.2 shows an example of one article, with details of the five article authors (i.e. authors A to E), appearing in separate rows.

Table 5. 2: WoS author data table

Article ID	Publication year	Author's name	Email address	Organisation	Country
WOS:000277860700013	2010	A	A@xyz	CIMMYT	Zimbabwe
WOS:000277860700013	2010	B	B@xyz	CIMMYT	Zimbabwe
WOS:000277860700013	2010	C	C@xyz	Bunda Coll Agr	Malawi
WOS:000277860700013	2010	D	D@xyz	CSIRO Sustainable Ecosyst	Australia
WOS:000277860700013	2010	E	E@xyz	Wageningen Univ	Netherlands

The third table contained information about subject journal categories; namely, article ID, publication year, and journal subject category (see Table 5.3). The third table could be linked back to the first and second tables based on the article IDs. For instance, the first article in Table 5.3 below, appeared in a journal called *Anaesthesia and Intensive Care*, which has been classified by Clarivate Analytics as belonging to two subject category: 'anesthesiology' and 'critical care medicine'.

Table 5. 3: WoS data table of journal subject categories

Article ID	Publication year	Journal subject category
WOS:A1980KR50300018	1980	Anesthesiology
WOS:A1980KR50300018	1980	Critical Care Medicine
WOS:000277860700013	2010	Agriculture, Multidisciplinary
WOS:000393038900002	2016	Management

The WoS subject category classification of journals was also used to assign articles to one or more of six broad fields (agricultural sciences; engineering and technologies; health sciences; humanities; natural sciences; and social sciences). This stage is discussed in detail in Step 9.

<u>Step 2: Scopus data</u>

The second step was to gather all Zimbabwean articles indexed in Scopus. These articles were downloaded on 5 February 2018, from the online Scopus database to which Stellenbosch University subscribes. A three-fold search strategy was employed; namely: (i) documents of the 'article type', (ii) with at least one Zimbabwean author address, and (iii) covering the period 1980-2016 were selected. Generally, Scopus allows a limited number of articles to be downloaded at a time; hence, articles were downloaded in a series of seven separate files. Altogether, a total of 8 818 articles were downloaded. The files contained in each column key information about article and author details; namely, article IDs, year of publication, affiliations, author names together with their affiliation, abstracts, funding details, correspondence addresses, publisher, and document type.

An article data table for Scopus (similar to the article data table for WoS – see Table 5.1) could easily be created. However, unlike the WoS data at CREST, author names and affiliations in the Scopus database were in string formats, as shown in Table 5.4. This meant that the creation of an author data table (similar to the one for WoS – see Table 5.2) presented a challenge.

Table 5. 4: Scopus author table 1

Article ID	Authors' names and address
2-s2.0-85008502049	Author A, Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare, Zimbabwe; Author B, MRC Tropical Epidemiology Group, London School of Hygiene and Tropical Medicine, London, United Kingdom; Author C., Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare, Zimbabwe;

The names of authors and their affiliations were split to ensure that each author's details were contained in a separate row (see Table 5.5). The splitting process was two-fold. Firstly, the semicolon was used as a delimiter to separate authors and have them placed in rows, as shown in Table 5.5 below.

Table 5. 5: Scopus author table 2

Article ID	Author's name and address
2-s2.0-85008502049	Author A, Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare, Zimbabwe
2-s2.0-85008502049	Author B, MRC Tropical Epidemiology Group, London School of Hygiene and Tropical Medicine, London, United Kingdom, University of Zimbabwe, Department of Community Medicine, Harare, Zimbabwe
2-s2.0-85008502049	Author C, Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare, Zimbabwe

Secondly, a coma was used as a delimiter to separate each author from their affiliation so that the name and address appeared in two separate columns, as shown in Table 5.6.

Table 5. 6: Scopus final author table

Article ID	Author's name	Address	Country
2-s2.0-85008502049	Author A	Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare	Zimbabwe
2-s2.0-85008502049	Author B	MRC Tropical Epidemiology Group, London School of Hygiene and Tropical Medicine, London, United Kingdom, University of Zimbabwe, Department of Community Medicine, Harare	Zimbabwe
2-s2.0-85008502049	Author C	Zimbabwe AIDS Prevention Project, University of Zimbabwe, Department of Community Medicine, Harare	Zimbabwe

Step 3: Unification of Scopus and WoS articles

Once all authorship details in Scopus had been separated, the next step was to combine the Scopus and WoS articles to create a new database of Zimbabwean articles. The combined dataset consisted of a total of 16 969 non-unique articles. Of these, 2 881 were in Scopus only; 5 937 were Scopus articles that were also contained in WoS; 2 229 were in WoS only; and 5 922 were WoS articles that were also in Scopus.

The articles from the two databases were subsequently unified in Microsoft Excel to produce a single dataset of unique articles. The unified data was then exported to a Microsoft Access database where it was systematically organised. During the unification process in Excel, WoS articles were treated as the main data source and only those Scopus articles not included in WoS were added to the main source. Table 5.7 shows how the two datasets were combined, with WoS as the main source. Details from rows 1 to 6 indicate that an article was indexed in both Scopus and WoS, while rows 7 and 8 show articles in WoS only. Articles in Scopus only appear in rows 9 and 10, and were the only Scopus articles to be added to the main source.

Table 5. 7: Unification of WoS and Scopus articles

Row	Year	Article ID (WoS)	Article ID (Scopus)	Decision	Article ID (final)
1	2008	WOS:000259537000010	2-s2.0-54249144534	Article in both WoS & Scopus; select WoS	WOS:000259537000010
2	1982	WOS:A1982PY91700001	2-s2.0-0020434167	Article in both WoS & Scopus; select WoS	WOS:A1982PY91700001
3	2008	WOS:000252909500005	2-s2.0-36448981353	Article in both WoS & Scopus; select WoS	WOS:000252909500005
4	1980	WOS:A1980KN70800002	2-s2.0-0019069018	Article in both WoS & Scopus; select WoS	WOS:A1980KN70800002
5	2003	WOS:000186338100007	2-s2.0-0345329469	Article in both WoS & Scopus; select WoS	WOS:000186338100007
6	1985	WOS:A1985ARU1200016	2-s2.0-0022247465	Article in both WoS & Scopus; select WoS	WOS:A1985ARU1200016
7	2000	WOS:000165131700009	--	Article in WoS only; include	WOS:000165131700009
8	2015	WOS:000365041700021	--	Article in WoS only; include	WOS:000365041700021
9	2011	--	2-s2.0-84948783528	Article in Scopus only; include	2-s2.0-84948783528
10	2014	--	2-s2.0-84905457487	Article in Scopus only; include	2-s2.0-84905457487

Step 4: Data cleaning

Having combined the WoS and Scopus datasets, Step 4 involved data cleaning. The combined dataset was subjected to a series of manual cleaning and consistency checks in Microsoft Access. The cleaning process entailed removing all duplicates; removing all articles erroneously assigned to Zimbabwe; and removing some documents erroneously coded as articles.

Step 5: Scopus and WoS unique article dataset

Once all duplicates and all articles erroneously assigned to Zimbabwe had been removed, a final, unique article dataset was created for the period 1980-2016. A new variable with three mutually exclusive categories was also included in the dataset: (i) Scopus articles only, (ii) WoS articles only, and (iii) both Scopus and WoS articles (see Table 5.8).

Table 5. 8: Creation of a Scopus and WoS unique article dataset

Year	Article ID (Scopus)	Article ID (WoS)	Article ID (final)	New variable
2012		WOS:000385709600009	WOS:000385709600009	WoS articles only
2015		WOS:000334096800004	WOS:000334096800004	WoS articles only
2011	2-s2.0-84948783528		2-s2.0-84948783528	Scopus articles only
2014	2-s2.0-84905501415	WOS:000073904100005	WOS:000073904100005	Both Scopus and WoS articles
2014	2-s2.0-84905457487		2-s2.0-84905457487	Scopus articles only

The final database comprised 10 753 unique articles produced by researchers in Zimbabwe during the period 1980-2016. Of this total, 2 834 (26%) were articles indexed in Scopus only, 1 992 (19%) in WoS only, and the majority, 5 927 (55%), in both Scopus and WoS, as illustrated in Figure 5.2.

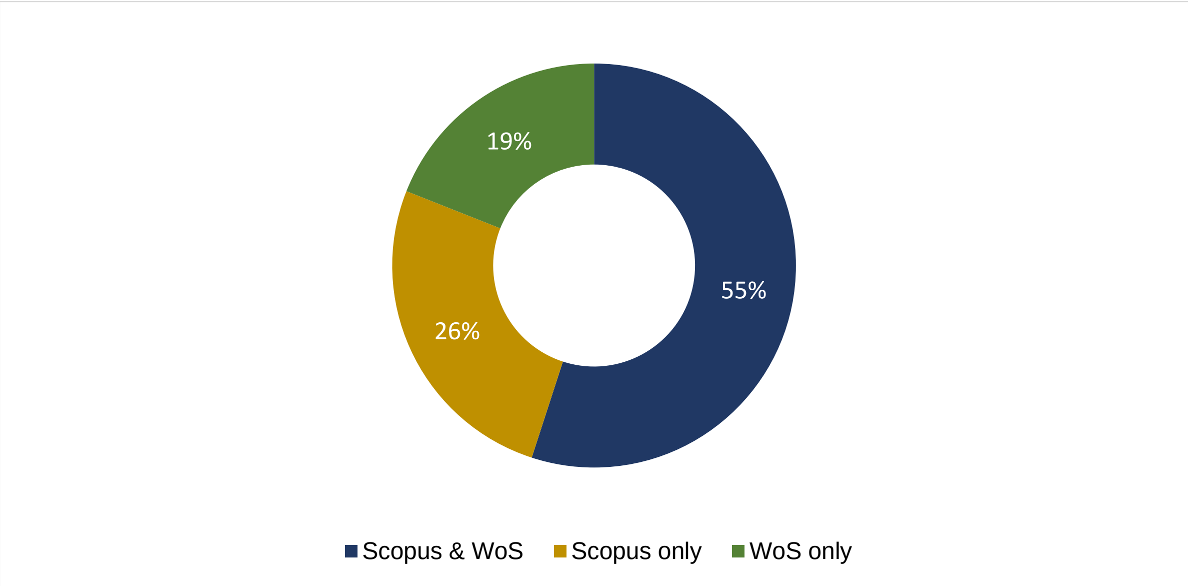

Figure 5. 2 : Unique dataset of Zimbabwean articles, based on Scopus and WoS, 1980-2016 (n=10 753)

<u>Step 6: NRDZ data</u>

As already explained in Chapter 1, articles from Zimbabwe's national research database (i.e. the NRDZ) were used in the study to provide additional articles to the two mainstream data sources. A total of 1 357 bibliographic records classified as journal articles, covering the period 2012-2016, were downloaded from the online NRDZ on 18 March 2018. The reason for starting in 2012 was that the NRDZ was established as a searchable database in 2011 with consistent indexing only from 2012 onwards. The records were organised in Microsoft Access where they were assigned ID numbers. The records were contained in two tables. The first table contained key information about article details; namely, article ID, year of publication, title, journal, and abstract (see Table 5.9).

Table 5. 9: NRDZ article data table

Article ID	Publication year	Title	Journal	Abstract
10.	2016	Molecular Identification of Nontuberculous Mycobacteria in Humans in Zimbabwe Using 16S Ribosequencing.	*Open Microbiology Journal*	Xyz …
1096.	2012	Factors Influencing Lecturer Research Output In New Universities In Zimbabwe.	*Zimbabwe Journal of Educational Research*	Xyz …
1796.	2013	The effects of maize meal particle size distribution on broiler performance.	*Midlands State University Journal of Science, Agriculture and Technology*	Xyz …
2447.	2016	Limitation of human rights in international law and the Zimbabwean Constitution.	*Zimbabwe Electronic Law Journal*	Xyz …

The second table contained information about authors' details; namely, author's name, address, country, and email address (see Table 5.10, for an example of author details for one article). All details in the author data table could be linked back to the article data table based on the article IDs.

Table 5. 10: NRDZ author data table

Article ID	Authors	Address	Country	Email
10.	Author A	National Microbiology Reference Laboratory	Zimbabwe	A@xyz
10.	Author B	National Microbiology Reference Laboratory	Zimbabwe	B@xyz
10.	Author C	Molecular Microbiology Laboratory, Department of Medical Microbiology, University of Zimbabwe	Zimbabwe	C@xyz
10.	Author D	Molecular Microbiology Laboratory, Department of Medical Microbiology, University of Zimbabwe	Zimbabwe	D@xyz

Step 7: Data cleaning of NRDZ articles

Step 7 entailed the cleaning of the NRDZ records. As a first step, a total of 306 duplicates were identified and removed from the dataset. This resulted in a total of 1 051 unique records. The records were then checked against the combined Scopus and WoS database (see step 5) to identify matching articles. Table 5.11 shows the IDs of NRDZ articles, matched against those of Scopus and WoS articles.

Table 5. 11: NRDZ, Scopus and WoS article data table

Year	Source	Article ID (Scopus)	Article ID (WoS)	Article ID (NRDZ)
2013	WoS only		WOS:000322504700003	1689.
2014	WoS only		WOS:000335197200002	1678.
2013	Both	2-s2.0-84872804698	WOS:000313973400004	1676.
2015	WoS only		WOS:000362266800004	1664.
2015	Both	2-s2.0-84928248294	WOS:000361792200003	1647.

Of the 1 051 records, 168 (16%) appeared in the Scopus and WoS database. The remaining articles (i.e. those not in Scopus and WoS) were subjected to online screening in order to locate their full-text versions. The searches led to the identification of records other than journal articles including document types such as reports, books and theses. The search also identified articles that did not appear in any other database or on the Internet (i.e. articles that were listed only in the NRDZ). Table 5.12 shows the distribution of records incorrectly classified as journal articles. It shows that most of these records (221 or 21%) were documents that were only listed in the NRDZ and not in any other database, or even on the World Wide Web.

Table 5. 12: Records wrongly classified as Zimbabwean journal articles in the NRDZ, 2012-2016

Decision	Correct document type	Count	% of 1 051
'Article' that does not exist outside the NRDZ	(Unknown)	221	21%
Article that has no Zimbabwean author address	Journal article	48	5%
Not an article (other document type)	Book	1	<1%
	Book chapter	4	<1%
	Book review	1	<1%
	Conference paper	26	2%
	Newspaper	18	2%
	Report	3	<1%
	Thesis	2	<1%
Total		**324**	**30%**

Table 5.12 shows that a total of 324 (30%) records were incorrectly classified as articles. These records were excluded from the final NRDZ dataset. The remaining articles (559) (i.e. those not in Scopus and WoS) were checked against the Beall's list (Beall, 2007) to identify articles in 'questionable' journals. In some cases, judgements about journals not on Beall's list were made based on the fact that journals had ceased to exist after a few editions or had questionable journal metrics. This exercise was done since the NRDZ is a national repository. It is perceived that some of the content in repositories can be "questionable" and "below standard" (Raju & Raju, 2009). Articles not considered questionable were classified as either

'article in Zimbabwean journal' or 'article in international journal not indexed in Scopus or WoS'. Figure 5.3 shows all the document types originally classified as journal articles in the NRDZ.

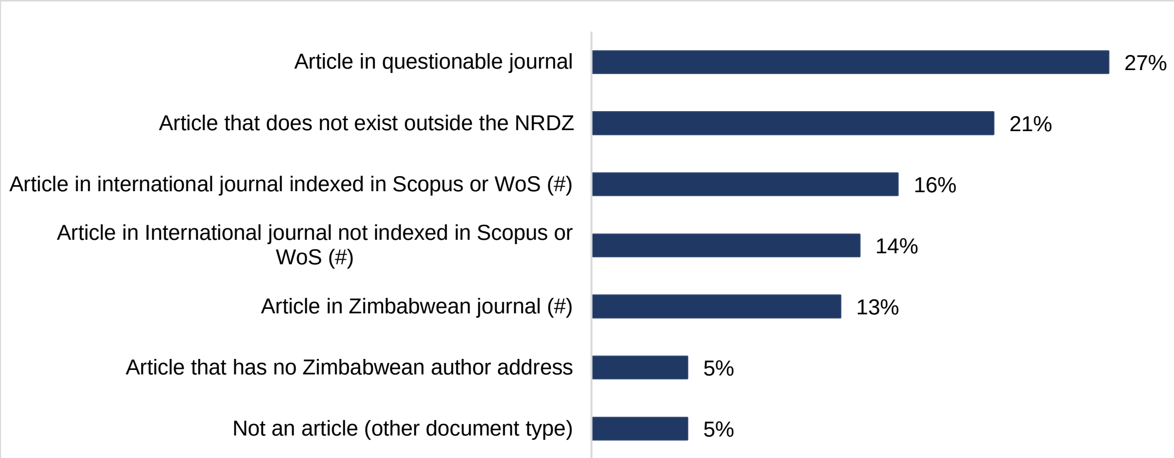

Figure 5. 3: Full distribution of records classified as journal articles in the NRDZ, 2012–2016 (n=1 051)

(#) Articles that remained in the final NRDZ dataset.

As can be seen in Figure 5.3, the majority (281 or 27%) of 'articles' indexed in the NRDZ were articles in questionable journals. The figure shows that the database also had a large number of articles (221 or 21%) that did not exist outside the NRDZ. The database had a total of 168 (16%) articles that were also indexed in Scopus and WoS, and a total of 134 (13%) articles in Zimbabwean journals only. None of these Zimbabwean journals were indexed in either Scopus or WoS.

The final NRDZ dataset comprised 444 articles. Of these, 168 (38%) were articles in international journals indexed in Scopus and WoS; 142 (32%) were articles in international journals not indexed in Scopus and WoS; and 134 (30%) were articles published in Zimbabwean journals. Figure 5.4 below shows the composition of articles in the final NRDZ dataset.

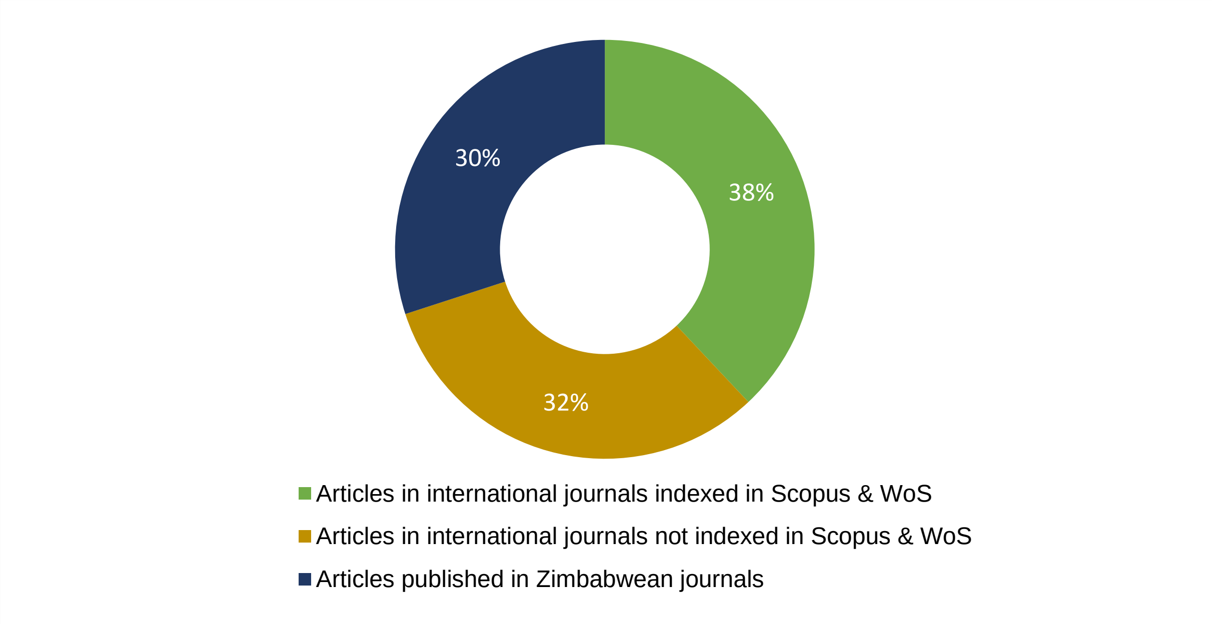

Figure 5. 4: Final NRDZ dataset, 2012-2016 (n=444)

Step 8: Unification of articles in Scopus, WoS and the NRDZ (2012-2016)

Step 8 involved unifying articles from the three data sources (i.e. Scopus, WoS and the NRDZ). Since the NRDZ only had articles published between 2012 and 2016, only articles from Scopus and WoS published in the same period were selected. A new variable with seven mutually exclusive categories was created. The categories comprised articles in:

- Scopus and WoS
- Scopus only
- WoS only
- NRDZ only
- Scopus, WoS, and the NRDZ
- Scopus and the NRDZ
- WoS and the NRDZ.

In total, the article database created from Scopus, WoS and NRDZ sources, for the period 2012-2016, comprised 2 935 articles. Figure 5.5 shows a breakdown of the coverage of articles by each data source. It shows that more than half of the articles, 1 650 or 56%, were indexed in both Scopus and WoS. Articles in Scopus only totalled 590 (20%), while those in WoS only totalled 254 (9%). The NRDZ contributed 277 (9%) unique articles.

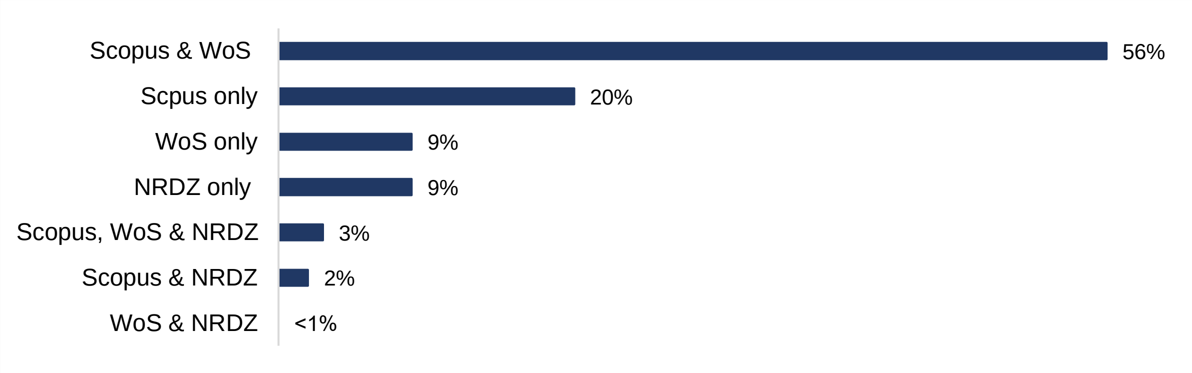

Figure 5. 5: Article dataset based on Scopus, WoS and NRDZ sources, 2012-2016 (n=2 935)

Step 9: Development of a field classification of journals

All journal titles in the final article database (the main database [step 5] and its enriched subset [step 8]) were subjected to a series of consistency checks and standardisation. Once standardised, each journal title was assigned to one or more of the following six broad fields: (i) agricultural sciences, (ii) engineering and technologies, (iii) health sciences, (iv) humanities, (v) natural sciences, and (vi) social sciences. Subject categories of journals in the WoS were firstly organised into the six fields outlined above, by applying the framework of Boshoff (2010). The titles of journals in Scopus and the field categories of Scopus journals were then used to classify Scopus journals into the same broad fields. Similarly, the titles of journals with articles unique to the NRDZ were used to classify NRDZ journals into the broad fields (for an example of classification of NRDZ journals see Table 5.13).

Table 5. 13: Field classification of NRDZ journals

Journal	Agricultural science	Engineering & technol-ogies	Health sciences	Humanities	Natural sciences	Social sciences
Research Journal of Agricultural Sciences	X					
University of Zimbabwe Business Review						X
Viruses			X			
Vulture News: The Journal of the IUCN Vulture Specialist Group					X	
Zimbabwe Journal of Educational Research						X
Zimbabwe Journal of Technological Sciences					X	
Zimbabwe Rule of Law Journal				X		

Table 5.14 shows more examples of how Scopus, WoS and NRDZ journals were aligned to the six broad fields.

Table 5. 14: Classification of journals into field categories

Article ID (final)	Journal	Subjects categories	Six broad field categories
1116.	*Zimbabwe Journal of Educational Research*	Education & Educational Research	Social sciences
1565.	*Journal of Language Teaching and Research*	Language & Linguistics	Humanities
1565.	*Journal of Language Teaching and Research*	Education & Educational Research	Social sciences
1567.	*International Journal of African Renaissance Studies - Multi-, Inter- and Transdisciplinarity*	Multidisciplinary Sciences	Natural sciences
1574.	*The Dyke*	Multidisciplinary Sciences	Natural sciences
2-s2.0-0028030433	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	Tropical Medicine	Health sciences
2-s2.0-0028035645	*Theoretical and Applied Genetics*	Agronomy	Agricultural sciences
2-s2.0-0028035645	*Theoretical and Applied Genetics*	Horticulture	Agricultural sciences
2-s2.0-0028035645	*Theoretical and Applied Genetics*	Plant Sciences	Agricultural sciences
2-s2.0-0028035645	*Theoretical and Applied Genetics*	Genetics & Heredity	Health sciences
WOS:000368420000017	*Water Resources Research*	Limnology	Natural sciences
WOS:000368420000017	*Water Resources Research*	Water Resources	Natural sciences
WOS:000368440500041	*Science*	Multidisciplinary Sciences	Natural sciences
WOS:000368472300009	*Tropical Conservation Science*	Biodiversity Conservation	Natural sciences
WOS:000368472300018	*Tropical Conservation Science*	Biodiversity Conservation	Natural sciences
WOS:000368505200006	*AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV*	Psychology, Multidisciplinary	Social sciences
WOS:000368505200006	*AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV*	Social Sciences, Biomedical	Social sciences

Journals could be assigned to more than one subject category. This means that the six broad fields were not mutually exclusive. An example is the *Biomass and Bioenergy* journal, which was classified in three fields; namely, the natural sciences, agricultural sciences, and engineering and technologies. The *Biomass and Bioenergy* journal belongs to the agricultural engineering (agricultural sciences), energy and fuels (engineering and technologies), and biotechnology and applied microbiology (natural sciences) subject categories, as shown in Table 5.15.

Table 5. 15: Example of a single journal classified in three broad fields

Article ID (final)	Journal	Subject categories	Broad fields
WOS:000253276300007	*Biomass and Bioenergy*	Agricultural Engineering	Agricultural sciences
		Energy & Fuels	Engineering & technologies
		Biotechnology & Applied Microbiology	Natural sciences

Step 10: Classification of Zimbabwean sectors

Step 10 involved the classification of Zimbabwean sectors. The 10 987 articles (total of Scopus, WoS, and the NRDZ) produced during the period 1980-2016 generated a total of 48 683 author addresses. These addresses were subjected to consistency checks. The final standardised dataset consisted of 47 971 author addresses, comprising both Zimbabwean and international addresses. A unified list of Zimbabwean organisations was then constructed from the standardised article author addresses. During the unification process, all variations of a name in the data were considered and changed to a single name. For instance, the University of Zimbabwe had four variants of its name; namely, “UZ”, “Univ of Zimbabwe”, “Univ of Zim”, and “University of Zimbabwe”. These were changed to “University of Zimbabwe”. The names of ministries posed a problem because they changed over time. For example, the Ministry of Health and Child Care was previously referred to as the Ministry of Health and Child Welfare. For all ministries, the name used at the time the study was carried out was used as the default name. Table 5.16 shows how a unified list of Zimbabwean organisations was created.

Table 5. 16: Unified list of Zimbabwean organisations

Address	Zimbabwean organisation
Zimbabwe Museum Human Sci, Harare, Zimbabwe	Zimbabwe Museum of Human Sciences
Zimbabwe Museum of Human Sciences, Harare, Zimbabwe	Zimbabwe Museum of Human Sciences
Zimbabwe Museum of Human Sciences, Zimbabwe	Zimbabwe Museum of Human Sciences
Bulawayo Sch Mines, Dept Mining, Bulawayo	Zimbabwe School of Mines
Zimbabwe, Sch Mines, Bulawayo, Zimbabwe	Zimbabwe School of Mines
Univ Zimbabwe, CASS, Harare, Zimbabwe	University of Zimbabwe
University of Zimbabwe, Harare, Zimbabwe	University of Zimbabwe
University of Rhodesia	University of Zimbabwe
UZ, Harare, Zimbabwe	University of Zimbabwe
Ministry Community Dev & Women’s Affairs, Harare, Zimbabwe	Ministry of Women’s Affairs, Gender and Community Development
Ministry Community Dev & Women’s Affairs, Salisbury Zimbabwe	Ministry of Women’s Affairs, Gender and Community Development
Ministry of Health	Ministry of Health and Child Care
Ministry of Health and Child Welfare	Ministry of Health and Child Care
Min of Hth and Child Care	Ministry of Health and Child Care
Mpilo Central Hospital, Bulawayo, Zimbabwe	Mpilo Central Hospital
Mpilo Cent Hosp, POB 2096, Bulawayo, Zimbabwe	Mpilo Central Hospital
Mpilo Hosp, Bulawayo, Zimbabwe	Mpilo Central Hospital

The standardised names of organisations generated 496 unique names of organisations in Zimbabwe. These organisations were classified into 13 sectors, as either a national organisation or an international national organisation (INO). The INO sector comprised four different types of organisations, namely:

1. Intergovernmental organisations that operate in Zimbabwe
2. International NGOs, philanthropic organisations, foundations, and think-tanks that operate in Zimbabwe
3. International research organisations, research networks or global research partnerships that operate in Zimbabwe
4. international businesses, companies and firms that operate in Zimbabwe.

The national sectors comprised eight different types of organisations, namely:

1. Zimbabwean university
2. Zimbabwean national and local government
3. Zimbabwean NGO/community-based organisation/faith-based organisation
4. Zimbabwean industry/business/company/firm
5. Zimbabwean private schools and training institutes
6. Zimbabwean private clinic/hospital
7. Zimbabwean mission/faith-based hospital
8. Zimbabwean union/association.

Table 5.17 shows the classification of Zimbabwean sectors, together with examples of organisations classified in each sector. A detailed analysis of these sectors and organisations is provided in Chapter 7.

Table 5. 17: Classification of Zimbabwean sectors

Eight sectors involving national organisations	**Four sectors involving INOs**
Zimbabwean university (e.g. National University of Science and Technology)	Intergovernmental organisation (e.g. Food and Agriculture Organization – Zimbabwe)
Zimbabwean national and local government (e.g. Department of Veterinary Services, Tsetse and Trypanosomiasis Control Branch)	International research organisation/network or global or regional research partnership that operates in Zimbabwe (e.g. International Crops Research Institute for the Semi- Arid Tropics)
Zimbabwean NGO/community based organisation/faith based organisation (e.g. Iluba Elimnyama Theatre Works)	International NGO/philanthropic organisation/foundation/think-tank that operates in Zimbabwe (e.g. Elizabeth Glaser Pediatric AIDS Foundation)
Zimbabwean industry/business/company/firm (e.g. National Foods Limited)	International business/company/firm that operates in Zimbabwe (e.g. Deloitte and Touche Zimbabwe)
Zimbabwean private schools and training institutes (e.g. Christian Brothers College)	Note: There is also a 13th sector, called ‘other’, which includes, for instance, unknown street and postal addresses.
Zimbabwean private clinic/hospital (e.g. Royal Women’s Clinic)	
Zimbabwean mission/faith-based hospital (e.g. Sanyati Baptist Hospital)	
Zimbabwean union/association (e.g. Zimbabwe Psychological Association)	

The sectors identified above were reclassified into five broad sectors; namely, university sector, government sector, INO sector, local NGO sector, and other sectors, as shown in Table 5.18. These broad sectors are referred to in the bibliometric results chapters.

Table 5. 18: Classification of five broad Zimbabwean sectors

Sectors	Notes
University sector	--
Government sector	--
INO sector	Refers to any one (or more) of the following sectors: intergovernmental organisations; international NGOs; international research organisations; and, international industry/businesses
Local NGO sector	--
Other sectors	Refers to any one (or more) of the following sectors: private hospitals and clinics; private schools and training institutes; mission or faith-based hospitals; unions and associations and, industry/businesses

Step 11: Development of a collaboration classification scheme

Having developed the classification of Zimbabwean sectors, the next step was to develop a collaboration classification scheme. As a first step, all articles were classified into one of the two authorship types; namely, single-authored or co-authored. The articles were then classified into the following four collaboration types:

- Collaboration type 1: Author addresses were coded as representing either national or international co-authorship. National co-authorship meant that all author addresses were Zimbabwean. International co-authorship indicated at least one international author address. These two codes were combined to generate the first indicator of co-authorship which consisted of:
    - Single-authored
    - National co-authorship only
    - International co-authorship only
    - Both national and international co-authorship.

- Collaboration type 2: All national co-authored articles were coded into two classification schemes; namely, co-authorship between institutions which indicates co-authorship between/among authors from different institutions in Zimbabwe; co-authorship within institutions which means co-authorship within the same institutions in Zimbabwe. These two codes were combined to generate the second indicator of collaboration which comprised:

- Co-authorship within institutions only
- Co-authored between institutions only
- Co-authorship between and within institutions.

- Collaboration type 3: The third collaboration indicator consisted of the sectors. For each of the six fields (i.e. agricultural sciences, engineering and technologies, health sciences, humanities, natural sciences, and social sciences), the most productive sectors were selected and coded into mutually exclusive categories. For instance, in the health sciences, the most productive sectors were: Zimbabwe (ZW) university sector, ZW government sector, and the ZW non-governmental organisation (NGO)/community-based/faith-based organisation only. These sectors were coded into seven mutually exclusive categories:
    - ZW university sector only
    - ZW national and local government sector only
    - ZW NGO/community-based/faith-based organisation only
    - Both ZW university and ZW national and local government sector
    - Both ZW university and ZW NGO/community-based/faith-based organisation
    - Both ZW national and local government sector and ZW NGO/community-based/faith-based organisation.

- Collaboration type 4: Co-authored articles were coded into: rest of Africa only, which refers to co-authorship between Zimbabwean authors and authors in the rest of Africa; and rest of world, which refers to co-authorship between Zimbabwean authors and authors in the rest of the world. These two codes were combined to generate a single variable consisting of:
    - Co-authorship with the rest of Africa
    - Co-authorship with the rest of the world
    - Co-authorship with both the rest of Africa and rest of the world.

<u>Step 12: Conversion of an article dataset into an author-level dataset</u>

In Step 12, the dataset of articles Scopus and WoS published between 2009 and 2016 was converted into a dataset of authors. This period was selected because prior to 2009 most articles did not have author names linked to addresses. In order to create the author-level dataset, unique author identifiers were manually assigned to all authors (both Zimbabwean and non-Zimbabwean) in an authorship table that was created from the article-level dataset.

After new identifiers had been assigned, the new dataset was populated with information about authors gathered from both the article and authorship tables. The following information was recorded:

- Number of Zimbabwean articles by an author
- Broad fields in which an author published
- Broad sector in which an author published
- Publication patterns for each author (i.e. whether they engaged in national or international or both national and international co-authorship).

The indicators for collaboration are discussed in detail in Step 14 below.

Figure 5.6 illustrates the transition from an authorship table in the article-level database to an author-level dataset. The new author dataset indicated in the bottom half of the figure shows the collaboration patterns of an author who authored articles presented in the top part of the figure. The relevant Zimbabwean author (A17551) produced four articles in the period 2009-2016, three of which with national co-authors only (3/4 = 75%) and one with both national and international co-authors (1/4 = 25%).

AUTHORSHIP TABLE CREATED FROM THE ARTICLE-LEVEL DATASET

	Article ID	Author ID	Address
Article 1 (3 authorships)	2-s2.0-84916204778	A17551	National University of Science and Technology, Zimbabwe
	2-s2.0-84916204778	A07330	National University of Science and Technology, Zimbabwe
	2-s2.0-84916204778	A18018	Great Zimbabwe University, Zimbabwe
Article 2 (7 authorships)	WOS:000281080100004	A17551	National University of Science and Technology, Zimbabwe
	WOS:000281080100004	A06853	United Nations Children's Fund, Zimbabwe
	WOS:000281080100004	A07347	United Nations Children's Fund, Zimbabwe
	WOS:000281080100004	A07420	United Nations Children's Fund, Zimbabwe
	WOS:000281080100004	A07428	Ministry of Health and Child Welfare, Zimbabwe
	WOS:000281080100004	A08234	National Microbiology Reference Laboratory, Zimbabwe
	WOS:000281080100004	A17963	University of Zimbabwe, Zimbabwe
Article 3 (5 authorships)	WOS:000297655100012	A17551	National University of Science and Technology, Zimbabwe
	WOS:000297655100012	A06007	National University of Science and Technology, Zimbabwe
	WOS:000297655100012	A07709	National University of Science and Technology, Zimbabwe
	WOS:000297655100012	A16905	University of Limpopo, South Africa
	WOS:000297655100012	A18536	University of Limpopo, South Africa
Article 4 (3 authorships)	WOS:000312840400001	A17551	National University of Science and Technology, Zimbabwe
	WOS:000312840400001	A02723	National University of Science and Technology, Zimbabwe
	WOS:000312840400001	A08043	National University of Science and Technology, Zimbabwe

AUTHOR-LEVEL DATASET

Author ID	Number of articles	% co-authored articles	% national co-authored articles only	% international co-authored articles only	% national and international co-authored articles
A17551	4	100%	75%	0%	25%

Figure 5. 6 : Classification of collaboration patterns of authors in an author-level dataset

Each author in the new author-level dataset was assigned to one or more of the six broad fields (i.e. field classification developed in the article-level database). Figure 5.7 shows the field classification of authors, based on the field table in the article-level dataset. Authors who published in journals classified in more than one subject category were assigned to the relevant broad fields.

FIELD TABLE CREATED FROM THE ARTICLE-LEVEL DATASET				
Article ID	**Author ID**	**Journal name**	**Journal subject categories**	**Broad fields**
2-s2.0-84985918673	A07125	*Clinical Infectious Diseases*	Immunology Infectious diseases Microbiology	Heath sciences Natural sciences
WOS:000355291000001	A07219	*Journal of Ethnobiology and Ethnomedicine*	Pharmacology & Pharmacy	Heath sciences
2-s2.0-65249138819	A19275	*Journal of Family Planning and Reproductive Health Care*	Family Studies; Obstetrics & Gynaecology; Social sciences, Biomedical	Heath sciences Social sciences
2-s2.0-77955675575	A06061	*Electronic Journal of Environmental, Agricultural and Food Chemistry*	Food Science & Technology; Environmental Sciences; Chemistry, Applied	Agricultural sciences Natural sciences

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AUTHOR-LEVEL DATASET						
Author ID	**Agricultural sciences**	**Engineering & technologies**	**Health sciences**	**Humanities**	**Natural sciences**	**Social sciences**
A07125	No	No	Yes	No	Yes	No
A07219	No	No	Yes	No	No	No
A19275	No	No	Yes	No	No	Yes
A06061	Yes	No	No	No	Yes	No

Figure 5. 7: Field classification of authors in an author-level dataset

Authors in the author-level dataset were also assigned to one or more of the five broad sectors. Figure 5.8 shows how authors in the author-level dataset were assigned to sectors, based on authorship details in the authorship table in the article-level database. The table shows authors affiliated to more than one sector.

AUTHORSHIP TABLE IN ARTICLE-LEVEL DATASET			
Article ID	**Author ID**	**Organisation with Zimbabwean address**	**National sector**
2-s2.0-68049105111	A15197	University of Zimbabwe	University
2-s2.0-68049105111	A15197	Zimbabwe Parks and Wildlife Management Authority	Government
2-s2.0-84881235918	A03788	United Nations Children's Fund (UNICEF)	INO
2-s2.084881605662	A18798	Kubatana Trust Fund	NGO

⬇

AUTHOR-LEVEL DATASET					
Author ID	**University**	**Government**	**NGO**	**INO**	**Other**
A15197	Yes	Yes	No	No	No
A03788	No	No	No	Yes	No
A18798	No	No	Yes	No	No

Figure 5. 8: Sector classification of authors in an author-level dataset

Step 13: Unique author dataset

Once the field and sector classification of authors had been completed, the final database of authors was created. This was done by using the 'group by' query function in Microsoft Access to return only one record for each set of unique author IDs. This resulted in the identification of a total of 11 606 authors. Of these, 2 896 were Zimbabwean authors (i.e. authors with at least one Zimbabwean address for any article produced during the period under review), and 8 710 were international authors (i.e. authors with only an international address for any article produced during the period under review), as shown in Figure 5.9. Of the 2 896 Zimbabwean authors, 400 (14%) also had a dual international address affiliation. A bibliometric analysis of Zimbabwean authors is provided in Chapter 9.

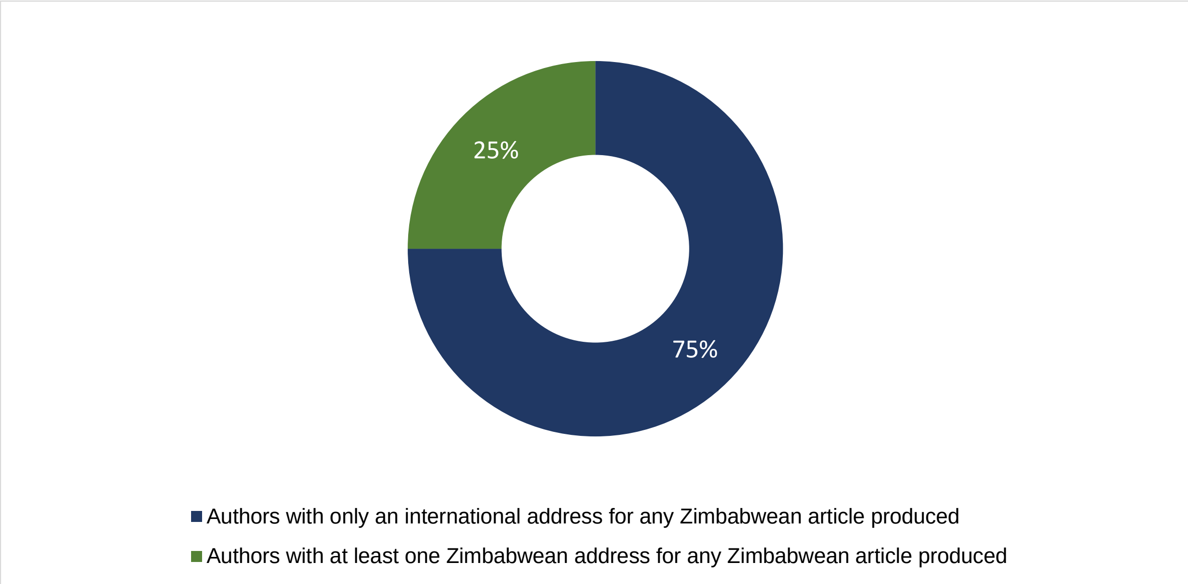

Figure 5. 9: Total number of authors contributing to Zimbabwean articles, 2009-2016

Step 14: Indicators for author-level analysis

Finally, two sets of author-level indicators – % of Zimbabwean authors with co-authored articles, and the mean % of co-authored articles per Zimbabwean author – were developed in order to analyse the trends and patterns of collaborating Zimbabwean authors. The difference between these two sets is that the second calculates the average percentage of co-authored articles per Zimbabwean author, while the first focuses on percentages of Zimbabwean authors with co-authored articles. Each of the two sets of indicators were divided into three sub indicators, as follows: The two sets of indicators are presented below.

- Set 1: The percentage of Zimbabwean authors who co-authored at least one article in the period 2009-2016 ('% of Zimbabwean authors who co-authored articles').
    - Three sub-indicators for set 1: The three parts are based on three mutually exclusive sets of authors: those who co-authored nationally only, internationally only, and both nationally and internationally.
- Set 2: The average percentage of co-authored articles produced by a Zimbabwean author in the period 2009-2016 ('Mean % of co-authored articles per Zimbabwean author').
    - Three sub-indicators for set 2: The three parts are again based on three mutually exclusive sets of co-authored articles: nationally co-authored only, internationally co-authored only, and both nationally and internationally co-authored.

The bibliometric analysis was performed in Microsoft Access by running database queries. The output was made visual in Microsoft Excel and Microsoft Word. The next section focuses on the survey method.

5.4 Survey method

An online survey of research collaboration and related activities in Zimbabwe was conducted. It is widely acknowledged that online/web-based surveys offer many advantages, including cost effectiveness, increased flexibility, and time efficiency (Barrios et al., 2011). The purpose of the survey was to explore other aspects and experiences of research collaboration that could not be captured by the bibliometric analysis. The survey focused on different groups of researchers; namely, emerging and established researchers, as well as researchers from different institutions in Zimbabwe. The steps taken to conduct the survey are presented in the sections that follow.

5.4.1 Development of the questionnaire

For the purpose of the online survey, a questionnaire was constructed. The questions were guided and informed by several sources. For example, the interview schedule used by Bozeman et al. (2016) in developing the model of research collaboration effectiveness provided valuable ideas, and some of the questions that Bozeman and his team used in other studies of research collaboration (Bozeman & Corley, 2004; Bozeman & Gaughan, 2011) were modified for the questionnaire. A full copy of the questionnaire is attached as Appendix 1. The questionnaire consisted of the following four main components:

1. The first component (Section A) solicited information about the collaboration activities of researchers in Zimbabwe. Some of these activities included: how often researchers engage in collaboration; with whom they collaborate; their reasons for collaborating; how collaborations are initiated; and the challenges encountered during collaborations.
2. The second component (Section B) focused on article authorship. The purpose of this section was to explore the article authorship practices of researchers in the country. The section also solicited information about disputes related to article authorship (i.e. how such disputes came about and how they were resolved).
3. The third component (Section C) focused on data ownership and data sharing. The purpose of this section was to understand the data ownership and sharing practices of researchers in the country. The section also sought to gather information about disputes related to data ownership (i.e. how such disputes came about and how they were resolved).
4. The last component (Section D) consisted of questions on the demographic details of researchers in the country including: gender, age, field, affiliation, highest qualification and where obtained, and career stage.

The first version of the questionnaire was reviewed and commented on by two specialists in research collaboration (at CREST, Stellenbosch University, South Africa). The questionnaire was also piloted with a group of researchers to ensure that the questions were well-defined and could be clearly understood.

5.4.2 Distribution of researchers in Zimbabwe

A database of published researchers and potentially research-active scholars was compiled and used to generate a distribution list for the online survey. The email addresses of published researchers were gathered from the list of Zimbabwean authors with articles published between 2012 and 2016 in the compiled bibliometric database (see Section 5.2.2. Step 5). The email addresses of potentially active researchers were downloaded online from the websites of universities and organisations. A three-fold search strategy was used to gather (i) those with at least a master's degree, (ii) whose email addresses were published in institutional websites, and (iii) were affiliated to a university or research organisation in Zimbabwe. The list of organisations and the count of email addresses sourced from each organisation are provided in Table 5.19. Most respondents (1 169) were from public universities. Of these, 337 were from the University of Zimbabwe. It needs to be emphasised that the email addresses presented below were only for those organisations that published emails of individuals on their websites, and where the relevant individuals indicated that they had at least a masters' degree.

Table 5. 19: Total number of email addresses sourced from websites of organisations in Zimbabwe

Name of organisation	Number of email addresses sourced
University of Zimbabwe	337
Great Zimbabwe University	305
Midlands State University	220
National University of Science and Technology	138
Chinhoyi University of Technology	43
Africa University	43
Bindura University of Science Education	39
Harare Institute of Technology	37
Department of Research and Specialist Services (DRSS) - Matopos Research Station	29
Scientific and Industrial Research and Development Centre	9
Lupane State University	6
Tobacco Research Board (Kutsaga)	1
National History Museum Zimbabwe	1
Blair Research Laboratory	1
Zimbabwe Open University	1
Biomedical Research and Training Institute	1
Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR)	1
Total	**1212**

Email addresses from the two sources (i.e. bibliometric database and websites of organisations) were combined in order to generate a distribution list for the survey (see Figure 5.10). The figure shows that a total of 6 160 non-unique email addresses were compiled. Of these, 2 412 emails addresses were from Scopus, 2 169 were from WoS, 367 were from the NRDZ, and 1 212 were from the websites of Zimbabwe's research organisations. These email addresses were standardised, and duplicates were identified and removed, such that the final list consisted of a total of 3 046 unique email addresses.

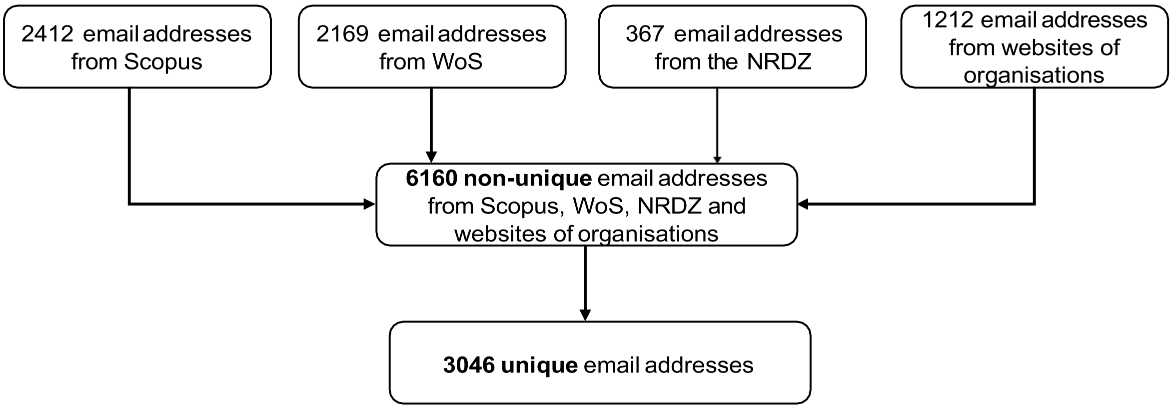

Figure 5. 10: Steps taken to create a standardised email address distribution list for the survey

The emails for the online survey were considered as representative of the total researcher workforce in the country. This is because, based on the only known country-wide survey on research and development, conducted by UNESCO in 2012, Zimbabwe had 2 739 headcount researchers and 1 315 FTE researchers (UNESCO, 2014).

5.4.3 Survey administration

An online survey (using SurveyMonkey) was developed. The questionnaire used in the survey was uploaded with the functionality that any data submitted online could be downloaded into an Excel file. An email explaining the objective of the survey and providing respondents with a hyperlink to access the questionnaire was sent to 3 046 Zimbabwean emails Participation in the survey was voluntary and researchers could opt out of completing the questionnaire at any given time. The first round of emails was sent out on 30 November 2018. Out of a total of 3 046 emails distributed, 654 (21.4%) bounced back. Thus, out of the total emails sent, 2 392 reached their intended targets. The second wave of emails was distributed on 21 December 2018. A total of 2 974 emails were sent out and 641 (21.5%) bounced back, meaning that 2 333 were successfully delivered.

Survey respondents

A total of 316 researchers responded to the questionnaire. This translated into a survey response rate of 13% of the 2 392 email addresses distributed, and which had reached their intended targets. This response rate was considered as adequately fair, based on a comparison with a response rate of 16.38% obtained in an online survey about the next generation of scientists in Africa, carried out between August and September in 2016. It needs to be noted that although 316 responses were received, the number of valid responses ranged from 220 to 259 as some questions were not fully completed.

Table 5.20 below compares the results of the online survey with those of the country's R&D survey, which was carried out in 2012 and published by UNESCO in 2014. This comparison was carried out in order to check for consistencies between the two surveys. Only public sector researchers (i.e. government and university sectors) are included in this comparison since the R&D survey only focused on public sector researchers. The table shows that out of the 197 researchers in the public sector who responded to the survey, 23% were female while 77% were male. These results correlate with the R&D survey which reported that of the 2 558 researchers with at least a master's or a PhD, 25% were female and 75% were male.[25] The table shows that of the 197 survey respondents who specified their highest level of qualification, 53% had a master's degree or equivalent while 47% had a PhD or equivalent. However, compared to the R&D survey, it is seen that more researchers had master's degrees (81%) while only 19% had a PhD or equivalent. One explanation for these differences could be that researchers who had master's degrees in 2012 could have advanced their studies and obtained PhDs, hence the 2018 percentages show a higher number of researchers with PhDs.

Table 5. 20: Total number of survey respondents, a comparison between survey results and the 2012 R&D survey of public researchers in Zimbabwe

Highest qualification	Online survey results (2018)						R&D survey (2012)					
	Females		Males		Total		Females		Males		Total	
Master's or equivalent	23	12%	82	42%	105	53%	525	21%	1 553	61%	2078	81%
PhD or equivalent	23	12%	69	35%	92	47%	127	5%	353	14%	480	19%
Total	**46**	**23%**	**151**	**77%**	**197**	**100%**	**652**	**25%**	**1 906**	**75%**	**2 558**	**100%**

The current study adds value to an understanding of the research workforce in Zimbabwe as it managed to obtain responses from a wider audience of researchers compared to the R&D survey that only reported on two sectors (i.e. the university and government sectors). According to the R&D survey report, out of a total of 2 558 researchers in Zimbabwe, 92% were in the university sector and 8% were in the government sector. Of the 230 researchers who responded to the current study, 81% indicated that they were in the university sector, 6% were in the government sector, 4% were in public research organisations, 5% in NGOs, and 3% were in the business sector. Hence, based on the results presented in this section, it can

[25] Note: The 181 researchers without a master's or PhD were excluded in this comparison.

be concluded that not only was the online survey representative, but it also contributes to the body of knowledge by presenting results from a wider audience of researchers in Zimbabwe.

5.3.4 Analysis of the survey data

Survey data were analysed using the statistical analysis software SPSS Version 26. An Excel file containing data from the online submissions was imported into SPSS. Once in SPSS, variables were defined, and a series of consistency checks were performed to ensure consistency of the data. Responses to open-ended questions were cleaned by standardising and creating new variables for statistical analysis. Data was analysed using (i) descriptive statistics, (ii) principal component analysis, and (iii) one-way analyses of variance. These are described in brief below.

- Descriptive statistics, as the name implies, are used to describe the features of the data in a study. They provide summaries about samples. In the current study, descriptive statistics provided general information on the profiles of the respondents and basic indicators for collaboration.
- A principal component analysis (PCA) is a data reduction technique. It produces a smaller number of linear combinations of original variables in a way that accounts for the variability in the pattern of correlations (Pallant, 2016). The PCA was performed on a set of items that reflect challenges faced by researchers during collaborations and on a set of items that capture different factors considered when choosing collaborators. The component analysis generated components reflecting challenges faced during collaborations and factors considered when choosing collaborators. The steps involved when performing a principal component analysis are presented in Section 10.6 and Section 10.7 in Chapter 10.
- The one-way analysis of variance (one-way ANOVA) is used to compare the mean scores of more than two groups. It involves one independent variable (component) which has a number of different levels. These levels correspond to the different groups. Pallant (ibid., p. 255) states that the one-way ANOVA compares the variance between the different groups (believed to be due to the independent variable) with the variability within each of the groups (believed to be due to chance). In the current study, one-way ANOVA was used to compare mean scores of components extracted after the PCA was performed. One-way ANOVA was used to determine whether challenges faced by researchers in the country differed according to regions and career stages, and also to compare how factors considered when choosing collaborators differed according to

regions and career stages of individuals. The steps involved when running one-way ANOVA are presented in Section 10.6 and Section 10.7

5.3.5 Coding of open-ended responses

The survey included a few open-ended questions. The responses to the open-ended questions provided a better understanding of research collaboration activities (i.e. issues that the quantitative approach could not address). Common recurring themes in the responses were identified in Excel, and the themes were assigned labels.

5.4 Ethical clearance

Permission to carry out the study was sought from the Research Council of Zimbabwe. A letter explaining the background and aim of the study was sent to the council. Permission to carry out the study was granted on 28 May 2018. Ethical clearance was also sought from the Research Ethics Committee (REC) of Stellenbosch University. Approval to carry out the study was granted by the REC on 3 July 2018 (REC-2018-7430).

5.5 Conclusion

The study employed a quantitative case study research design. This design was considered to be appropriate for the study as it allows investigations of contemporary phenomenon (the case) within real life context. The current study incorporated context into the bibliometric analysis. Additional context was provided by soliciting from Zimbabwean researchers, through a survey, responses to various aspects of research collaboration. The study employed two quantitative methods to examine the trends and patterns of research collaboration in Zimbabwe. Although the questionnaire contained some qualitative aspects, the study was predominantly quantitative and relied more on the bibliometric analysis. The survey served to complement and provide context for the bibliometric analysis.

The next five chapters present the results of the bibliometric analysis and the online survey. Chapter 6 provides a general profile of research production and research collaboration in Zimbabwe. Chapter 7 provides a detailed bibliometric analysis of research production and research collaboration of Zimbabwean organisations in the different national sectors. Chapter 8 focuses on the participation of ‘international national organisations’ (INOs) in Zimbabwean research. Chapter 9 provides the results of an author-level bibliometric analysis of the Zimbabwean research workforce responsible for articles published between 2009 and 2016. Finally, Chapter 10 presents findings from the online survey.

CHAPTER 6

Bibliometric analysis 1: General profile of research production and research collaboration in Zimbabwe

6.1 Introduction

This chapter presents a general bibliometric overview of the trends and patterns of research production and research collaboration in Zimbabwe, covering the period 1980-2016. By default, the analyses are based on the combined Scopus and Web of Science (WoS) database (Step 5 in Figure 5.1 in Chapter 5). Where the National Research Database of Zimbabwe (NRDZ) data are also included, it is explicitly indicated as such (Step 8 in Figure 5.1). Presented first is a profile of Zimbabwe's research output over the relevant period (Section 6.2), which incorporates the reflections on the representation of Zimbabwe's articles in the three data sources (i.e. WoS, Scopus and the NRDZ). Presented next, in Section 6.3, is a profile of research collaboration in Zimbabwe, as measured by instances of co-authorship. Section 6.4 focuses on the types of collaboration in which Zimbabwean researchers participate. All co-authored articles were classified into three broad types; namely, national collaboration, international collaboration, and both national and international collaboration. Lastly, Section 6.5 provides a summary profile of all co-authored articles in the country. In that section, all co-authored articles are broken down into seven mutually exclusive types of collaboration.

6.2 Research production in Zimbabwe, 1980-2016

Zimbabwe's total research output for the period 1980-2016, as measured by the numbers of articles in the Scopus and WoS databases, was 10 753. Figure 6.1 below shows the annual number of articles produced by the country during that period. As can be seen, the number of articles increased from 135 in 1980 to 673 in 2016, representing a compound annual growth rate of 4. 6%. Although the number of articles more or less steadily increased between 1980 and 1999, a decrease can be observed from 2000 onwards, which, in 2004, reached a 'low' of 220 articles. This decrease could largely be attributed to a series of socio-political challenges that affected the country's human capital base and R&D at the time. However, overall the figure shows upward growth, as indicated by the trend line, which demonstrates a positive correlation (R^2=0.648) in the annual article output in Zimbabwe at an average of 290 articles from 1980 to 2016. The overall trend towards positive growth is mainly because of a first peak in research production around 1996-1999, and a second and even higher peak around 2014-2016.

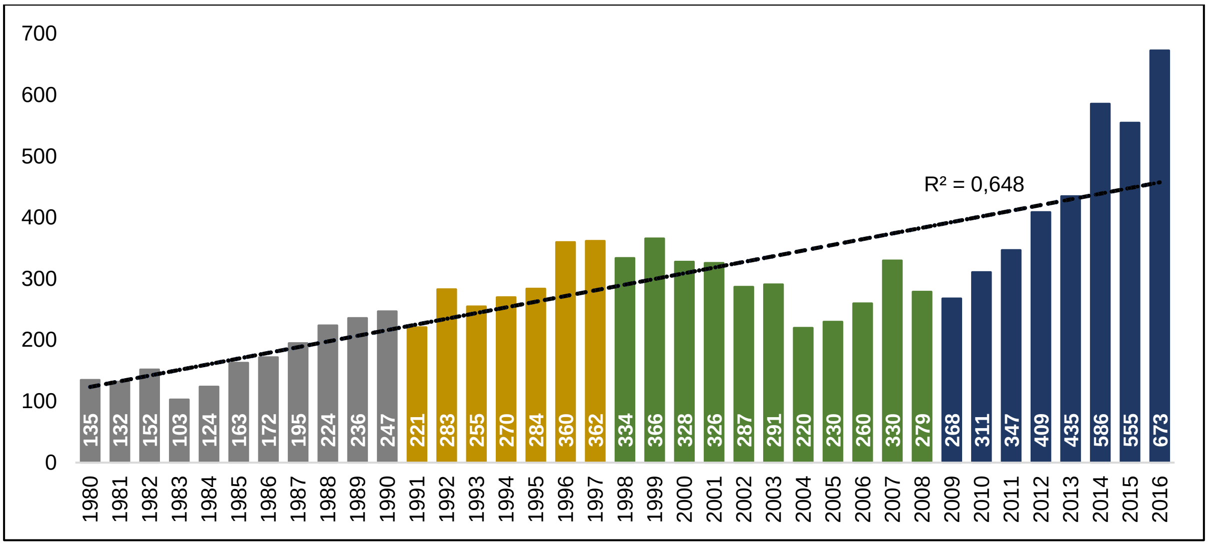

Figure 6.1: Annual number of articles produced by Zimbabwe, 1980-2016

Note: The different colours represent the four socio-political periods (i.e. period one, 1980-1990; period two, 1991-1997; period three, 1998-2008; and period four, 2009-2016).

Figure 6.2 shows a breakdown of the representation of Zimbabwean articles in each of the two mainstream bibliographic data sources (Scopus and WoS) for the period 1980-2016. The lines represent the total number of articles for Zimbabwe in each database (i.e. not the total number of Zimbabwean articles in the two data sources combined). Overall, Scopus had a higher coverage of Zimbabwean articles as compared to the WoS. Although WoS had a relatively higher coverage between 1980 and 1993, this tide turned in the years that followed. Interesting disparities are seen for the period 1995-2001. During this period, articles published in journals indexed in Scopus increased from 212 to 280 (32% increase) as compared to those in WoS, which rose from 183 to 221 (21% increase).

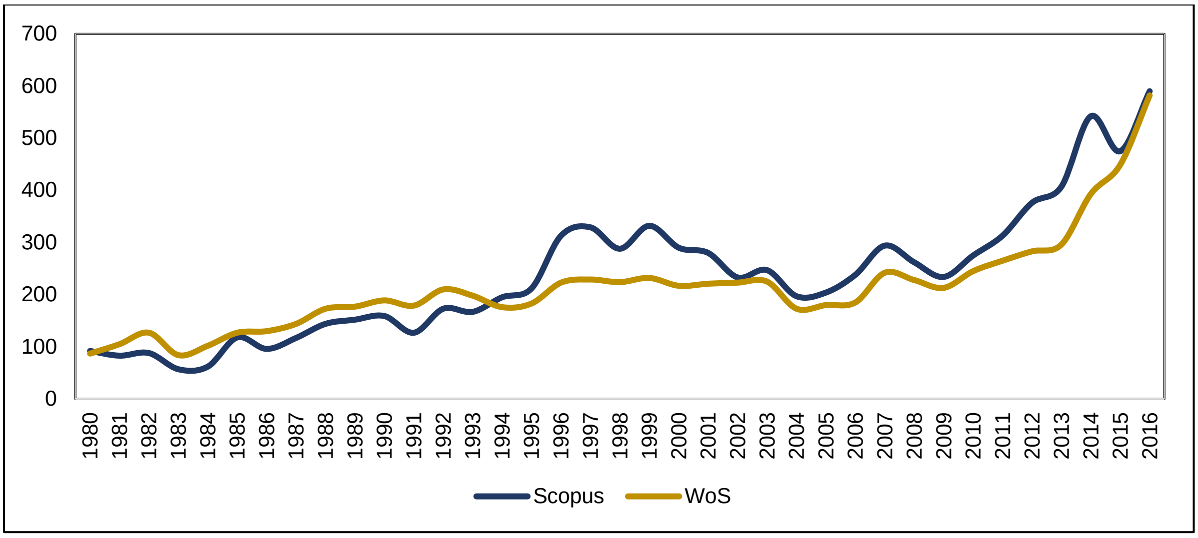

Figure 6.2: Annual number of Scopus and WoS articles produced by Zimbabwe, 1980-2016

Closer inspection of the individual journals indexed in Scopus and WoS showed that one journal, the *Central African Journal of Medicine*, was mainly responsible for the relatively large increase in the number of articles in Scopus between 1995 and 2001, and the decline in the number of articles in WoS during that period. Figure 6.3 shows that the WoS indexed articles published in the *Central African Journal of Medicine* from 1980 up until 1993. From 1994 onwards, the journal appeared only in Scopus. The high number of articles in Scopus between 1995 and 2001 could be explained by the fact Scopus indexed all issues of the *Central African Journal of Medicine* published during that period whereas, in the previous years, only selected issues might have been indexed (i.e. no back-to-back coverage of issues).

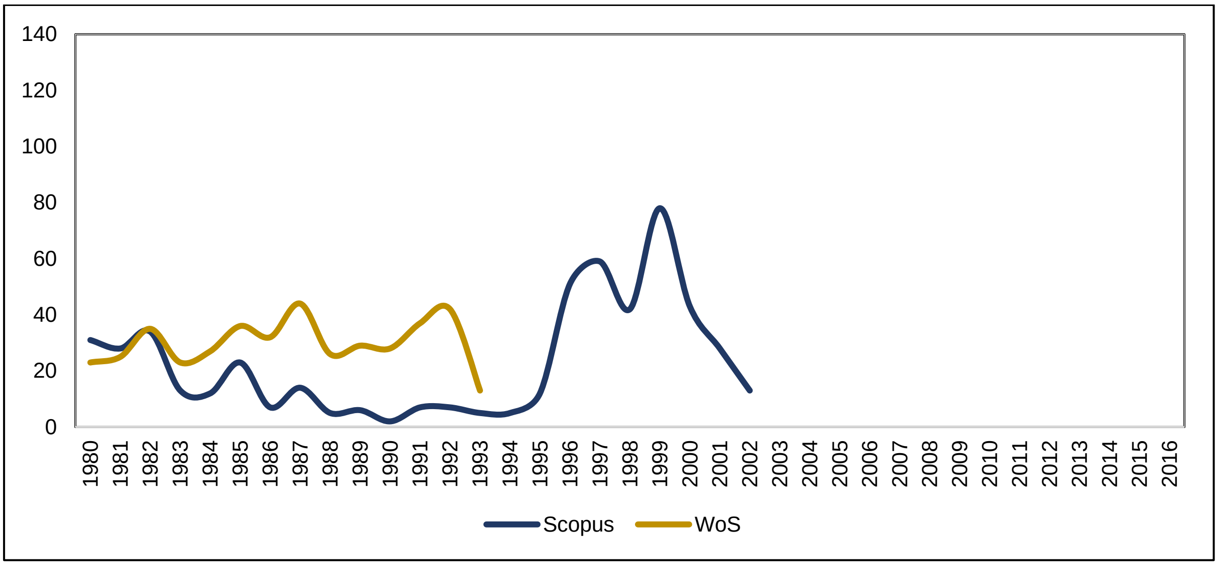

Figure 6.3: Annual number of articles in the *Central African Journal of Medicine* in Scopus and WoS, 1980-2016

It is generally argued that mainstream bibliographic databases such as WoS and Scopus do not always give true representations of African science. Therefore, the NRDZ was used in the study to reflect on the added value of using a national research database as a bibliometric data source. Figure 6.4 shows a breakdown of Zimbabwean articles between 2012 and 2016, as represented in WoS, Scopus and the NRDZ. The comparison starts in 2012, as the NRDZ was established in 2011, with consistent indexing only from 2012 onwards.

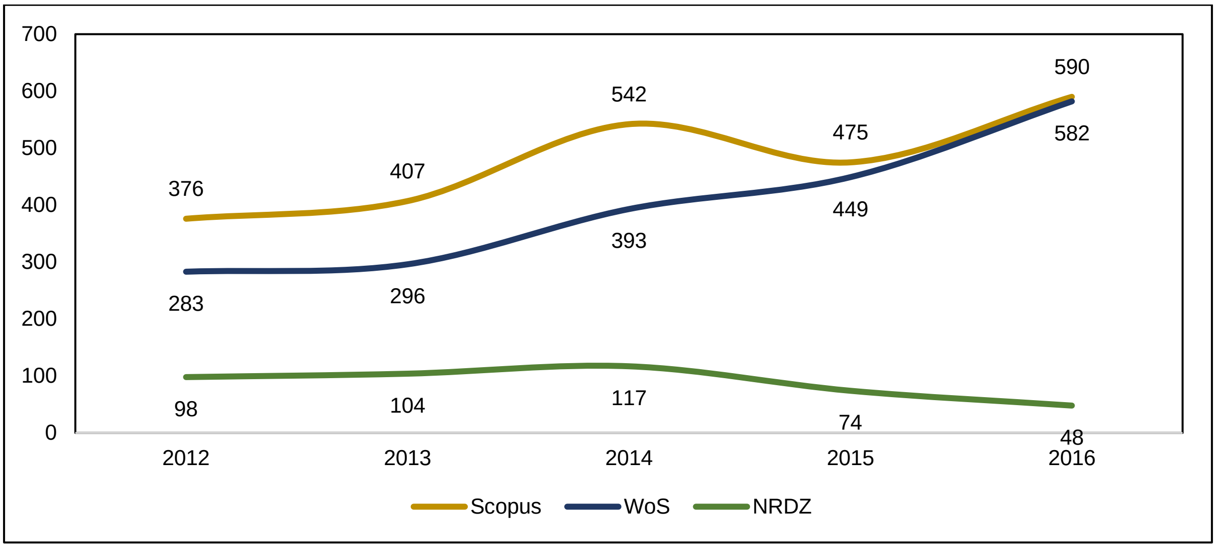

Figure 6.4: Annual number of Scopus, WoS and the NRDZ articles produced by Zimbabwe, 2012-2016

It can be seen in Figure 6.4 above that both Scopus and WoS had a higher coverage of Zimbabwean articles as compared to the national database. It is can also be seen that while articles indexed in Scopus and WoS increased with time, those in the NRDZ decreased significantly. Two possible reasons for this decline could be (i) the country had fewer articles published in journals not indexed in Scopus and WoS, or (ii) the NRDZ could be losing its initial appeal as a national repository, with researchers and institutions becoming less motivated to upload material to the database. One conclusion that can be drawn from data in the figure is that Scopus and WoS have a higher representation of Zimbabwe's articles, and that each on its own is a more reliable bibliographic data source than the NRDZ.

6.2.1 Research production by broad field

It is generally acknowledged that research production is field-specific. Hence, an assessment of the article output by six broad fields was done. The fields herein analysed are (i) agricultural sciences, (ii) engineering and technologies, (iii) health sciences, (iv) humanities, (v) natural sciences, and (vi) social sciences. Figure 6.5 below shows the total number of articles produced by the six fields per year, as represented in the combined Scopus and WoS databases.

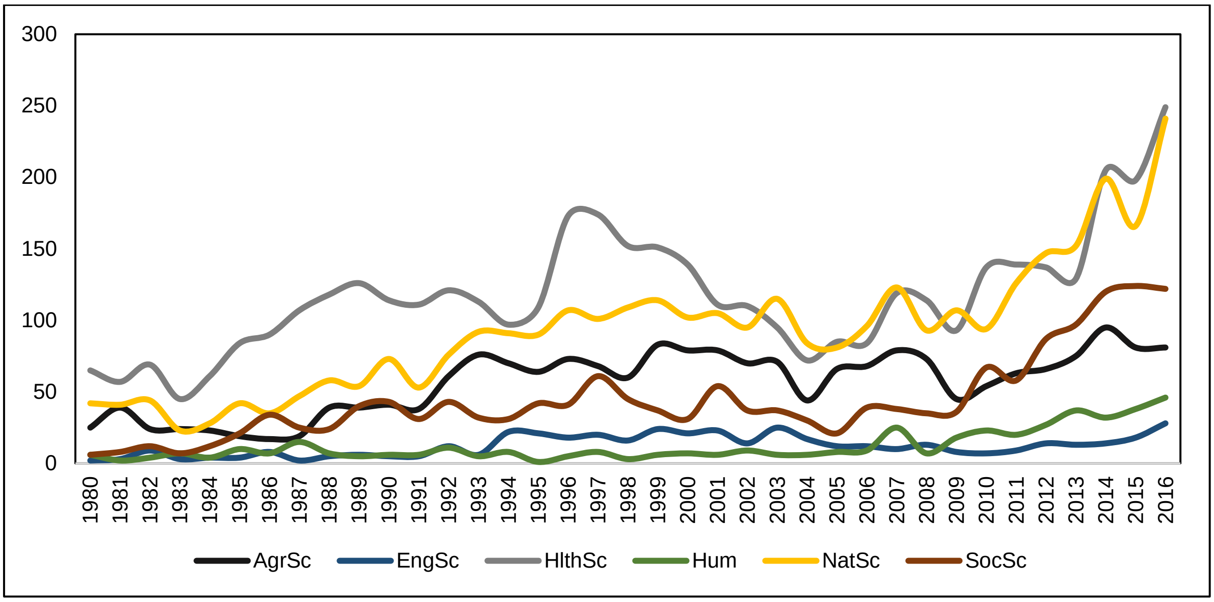

Figure 6.5: Annual number of Scopus and WoS articles produced by Zimbabwe, 1980-2016, by broad field

It is observed in Figure 6.5 that the health sciences were responsible for the largest share of articles in the country, especially between 1980 and 2003. A rather significant drop in article output in the health sciences is seen between 1996 and 2005 (from 173 to 81 articles). The peak and subsequent decline could partly relate to the coverage of health publications in Scopus, especially the coverage of the *Central African Journal of Medicine* (reduced coverage between 2000 and 2002, and no coverage since 2003 – see again Figure 6.3).

Figure 6.5 further shows that the natural sciences also made a significant contribution to the country’s total article output, in some years surpassing the contribution by the health sciences. The figure shows that the output gap between the health and natural sciences decreased from 2003 onwards, which indicates that the two fields produced almost the same number of articles. Since the field classification in Figure 6.5 is informed by the subject categories of journals, the similarity in output trends for the natural and health sciences might point to the presence of a set of multi-disciplinary journals that have subject categories in both the natural and health sciences. For this reason, an analysis of the overlap of journal subject classifications for the two fields was made, for the period 2003–2016 (Figure 6.6).

The relevant chart shows that there were 3 943 natural and health science articles produced between 2003 and 2016. Of this total, 1 824 (46%) appear in journals with subject categories in the natural sciences only, 1 856 (47%) appear in journals with subject categories in the health sciences only, while 263 (7%) appear in journals classified in both natural and health science. These results explain why the output gap between health and natural sciences was relatively small between 2003 and 2016. Both fields produced more or less the same number of articles. Only a few articles 263 (7%), were classified under both journals. For example, the *Diagnostic Microbiology and Infectious Disease* appeared in both health and natural sciences journals.

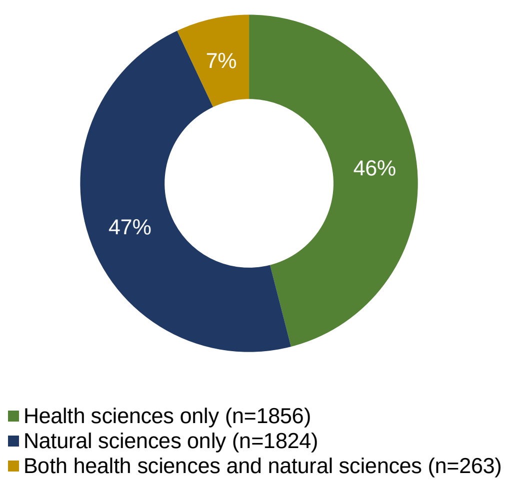

Figure 6.6: Journal subject classification for health and natural sciences articles, 2003-2016 (n=3 943)

Figure 6.7 shifts the focus to the combined dataset of Scopus, WoS and NRDZ articles for the period 2012–2016. It shows the counts of articles in each of the six broad fields, for the period 2012-2016, where the counts are disaggregated in terms of three mutually exclusive data source categories. The NRDZ defines two of the three categories. The objective is to determine in which broad fields the additional NRDZ data make the largest contribution.

Figure 6.7 shows that a total of 1 033 articles in this period could be classified as belonging to the natural sciences. Of these, 128 (12%) appeared exclusively in the NRDZ. The NRDZ's unique contributions in the other fields were 87(14%) and 30(14%) in social sciences and humanities, respectively. When only the social sciences were analysed, it was found that there were 499 (78%) articles represented in Scopus and WoS; 51 (8%) were indexed in all the three data sources; while 87 (14%) were in the NRDZ only. In general, although it can be concluded that Scopus and WoS have a high representation of all Zimbabwean field articles, the NRDZ cannot be ignored, especially with reference to the natural sciences and social sciences.

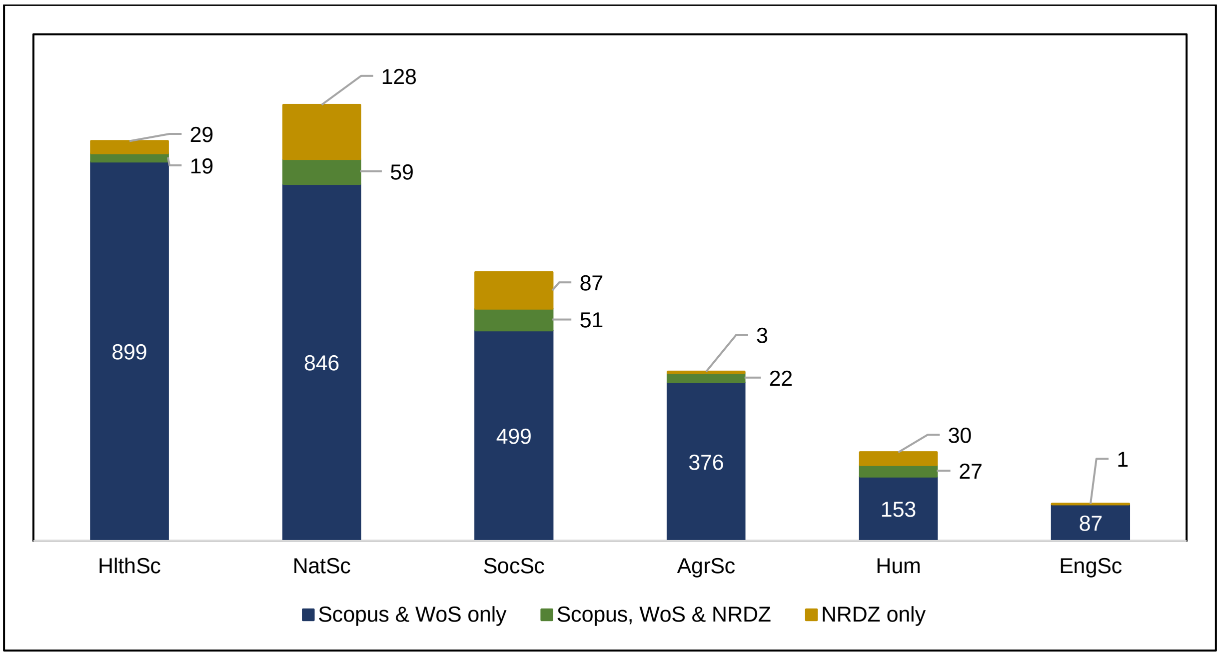

Figure 6.7: Number of articles by Scopus, WoS and the NRDZ and their overlap, 2012-2016, by broad field

6.2.2 Research production by sector

An assessment of Zimbabwe's article output by national sector was also made. The reader is referred back to Step 10 in Chapter 5, the methodology chapter, which explains how the 12 Zimbabwean sectors were constructed from the article author addresses. Table 5.5 in that chapter gives a list of the 12 sectors. For the following analysis, the 12 sectors were re-classified into five broad sectors, as shown in Table 6.1 below. The university sector, with a total article output of 7 131 (66%) for the period 1980-2016 was found to be the most productive sector in terms of research production in the country, as it was responsible for about two-thirds (66%) of article output during the relevant period. This was followed by the government sector with a total article output of 2 534 (24%), and the international national organisation (INO) sector, which comprises four sub-sectors as explained in the last column of Table 6.1, with a total of 1 193 (11%).

Table 6.1: Classification of Zimbabwean sectors into five broad sectors, with corresponding article counts for the period 1980–2016

Sectors	Total articles in Scopus or WoS, 1980–2016		Notes
	Count	As % of 10 753	
University sector	7 131	66%	--
Government sector	2 534	24%	--
INO sector	1 193	11%	Refers to any one (or more) of the following sectors: intergovernmental organisations; international NGOs; international research organisations; and, international industry/businesses
NGO sector	646	6%	--
Other sectors	445	4%	Refers to any one (or more) of the following sectors: Private hospitals and clinics; Private schools and training institutes; Mission or faith-based hospitals; Unions and associations and, Industry/businesses

Note: The sum of article counts exceeds 100% because any article can be classified in more than one sector in cases of co-authorship or in cases of authors with multiple affiliations.

An analysis of the annual number of the article output by the five sectors is provided in Figure 6.8.

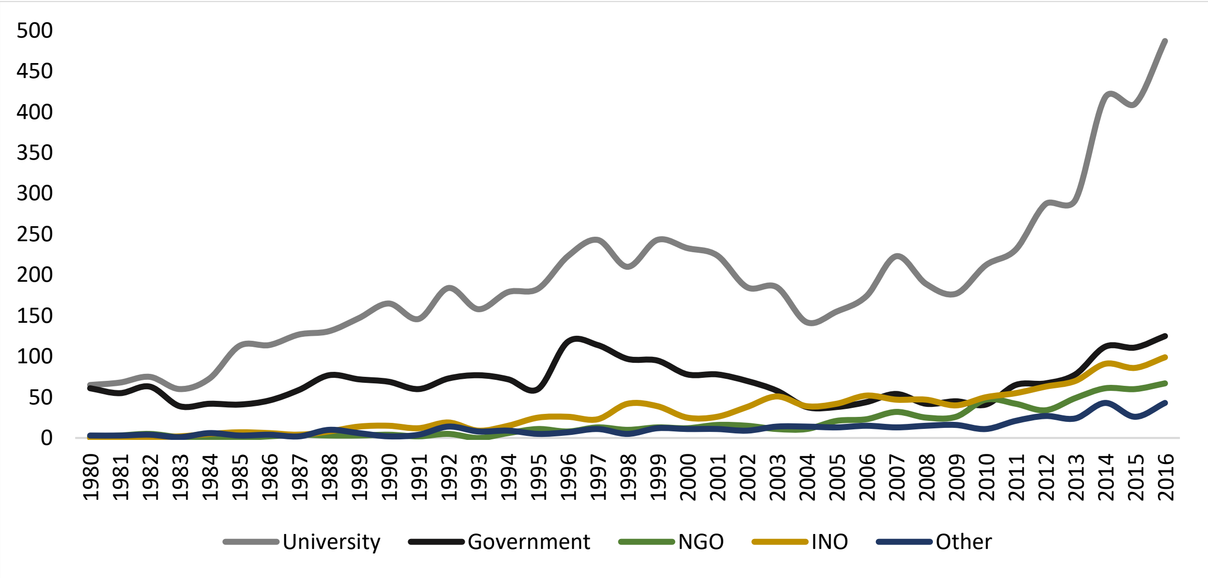

Figure 6.8: Annual number of Scopus and WoS articles produced in five Zimbabwean sectors, 1980-2016

Figure 6.8 shows that the annual number of articles produced by the government sector steadily increased between 1980 and 1996, from 61 articles to 118 articles, and decreased significantly from 1997, reaching a ‘low’ of 42 articles in 2005. This decrease could largely be attributed to socio-political challenges faced by the country at the time, which probably affected research production by the government sector. The figure shows that the contribution by the INO sector, although relatively low, increased consistently, especially from 1997 onwards, almost overlapping the share by the government sector. Table 6.2 compares the CAGR values for each of the five broad sectors in the period 1980 to 2016. It shows that the INO sector and the NGO sector had the highest compound annual growth rates, 14.5% and 12.4% respectively. Both these sectors have strong international influences as they both have access to international funding. The operations of NGOs tend to be primarily internationally funded whereas INOs are extensions of international organisations and therefore share the budget of their parent organisations.

Table 6. 2: Compound annual growth rate (CAGR) of five Zimbabwean sectors, 1980 to 2016

Sector	Compound annual growth rate (CAGR)
INO sector	14.5%
NGO sector	12.4%
Other sectors	7.5%
University sector	5.8%
Government sector	2.0%

Figure 6.9 confines the sector analysis to the last five-year period. It shows, for each sector, how the article output in that sector is expected to change should articles from the NRDZ be added. With the exception of the university sector, the addition of NRDZ data to the combined Scopus/WoS data did not make much difference. When only the university sector was analysed, it was found that only 272 (13%) of the articles in that sector appeared exclusively in the NRDZ, while 155 (7%) were simultaneously represented in all the data sources, and the majority 1 739 (80%) were indexed in the WoS and Scopus data sources. The unique contribution of the NRDZ to the article output in the government sector is only 4% (21 out of 514 articles).

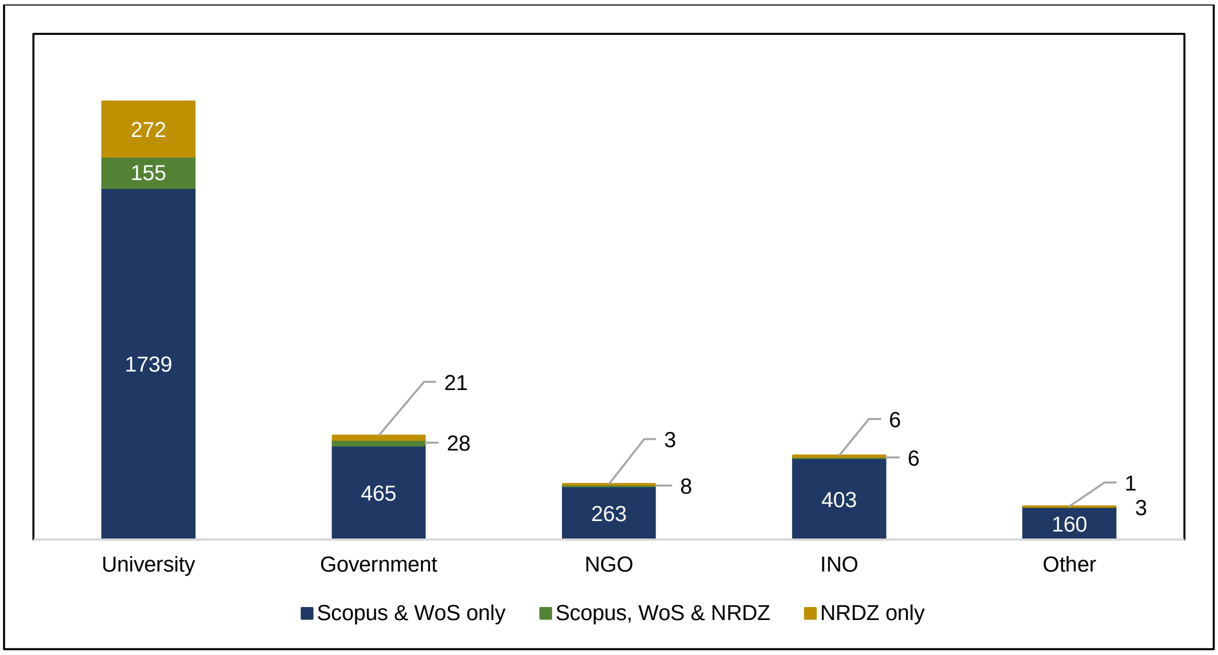

Figure 6.9: Number of articles by Scopus, WoS and the NRDZ and their overlap, 2012-2016, by broad sector

Finally, an analysis of article authorship was made to determine the mean number of authors responsible for the production of articles during the period under review (see Figure 6.10). The figure shows that the average number of article authors per year increased with time, from two article authors in 1980 to 10 in 2016. Although the number increased steadily throughout, a decrease can be observed in 2001, where the average number of article authors dropped from four authors in the year 2000 to three in 2001. This decrease could, at least in part, be attributed to the exodus of researchers from Zimbabwe to neighbouring countries due to the socio-political challenges prevailing in the country at the time.

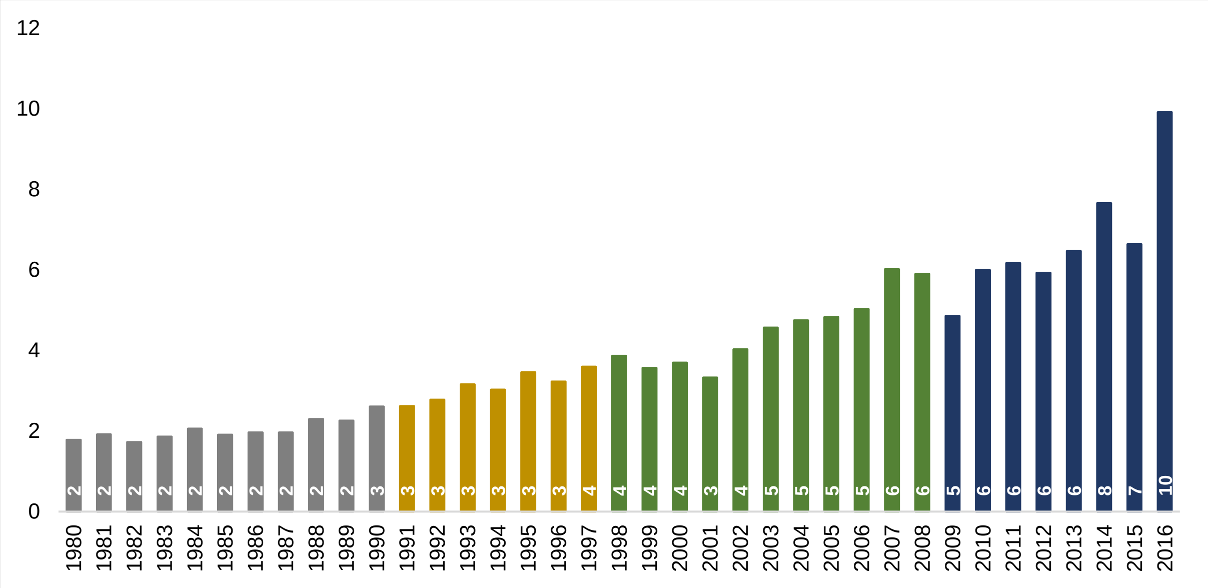

Figure 6.10: Average number of national and international article authors per year, 1980-2016

Table 6.3 shows a breakdown of the average number of article authors by broad field in four socio-political periods. The table shows that, overall, the average number of article authors per year in each of the six fields increased throughout the four socio-political periods. For example, in the first period, the 309 agricultural articles produced during the first year were contributions made by an average of two authors per article. However, in the last period, the 560 agricultural articles were accounted for by an average of five authors per article. A significant increase in article authors is seen in the field of health sciences (i.e. from an average of two authors per article in the first period to an average of 12 article authors in the last). Compared to other fields, the health sciences had articles produced by a large number of authors. For example, in the last period, at least one article in health sciences had a total count of 768 article authors. This means that the field of health sciences is likely to be involved in ‘bid science’ projects that span across nations.

In conclusion, it is noted that from 1980 onwards, the average number of article authors per year increased with time, which means that articles were increasingly being produced by multiple authorship. The next section (Section 6.3) focuses on the nature and types of article co-authorship.

Table 6. 3: Average number of article authors by broad field in four socio-political periods

Field by period	Average article authors per year	Standard deviation	Minimum number of authors	Maximum number of authors
AS: 1980-1990 (n=309)	2	1.5	1	9
AS: 1991-1997 (n=450)	3	1.9	1	11
AS: 1998-2008 (n=772)	4	2.0	1	24
AS: 2009-2016 (n=560)	5	2.7	1	26
NS: 1980-1990 (n=487)	2	1.4	1	8
NS: 1991-1997 (n=610)	3	2.4	1	29
NS: 1998-2008 (n=1 117)	4	2.9	1	30
NS: 2009-2016 (n=1 232)	7	15.6	1	350
HS: 1980-1990 (n=936)	2	0.6	1	18
HS: 1991-1997 (n=898)	4	3.6	1	45
HS: 1998-2008 (n=1 232	7	8.9	1	185
HS: 2009-2016 (n=1 287)	12	36.1	1	768
SS: 1980-1990 (n=232)	2	1.0	1	6
SS: 1991-1997(n=281)	2	2.0	1	19
SS: 1998-2008 (n=404)	4	11.5	1	131
SS: 2009-2016 (n=711)	3	2.9	1	41
HU: 1980-1990 (n=73)	1	0.9	1	8
HU: 1991-1997 (n=44)	2	5.9	1	40
HU: 1998-2008 (n=92)	2	1.4	1	9
HU: 2009-2016 (n=241)	2	2.1	1	28
ET: 1980-1990 (n=51)	1	0.6	1	3
ET: 1991-1997 (n=104)	2	1.2	1	7
ET: 1998-2008 (n=187)	3	1.9	1	18
ET: 2009-2016 (n=111)	4	1.9	1	12

Note: AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

6.3 Research collaboration in Zimbabwe, 1980-2016

The previous sections presented an analysis of Zimbabwe's article output by field and by sector. This section presents a profile of research collaboration in Zimbabwe as measured by co-authorship. Out of a total of 10 753 articles produced by the country between 1980 and 2016, 8 468 (79%) involved collaboration. Figure 6.10 shows the yearly output of co-authored articles generated over the study period. It is observed that the share of co-authored articles generally increased from 68 (50%) in 1980 to 606 (90%) in 2016, reaching a plateau from 2009 onwards.

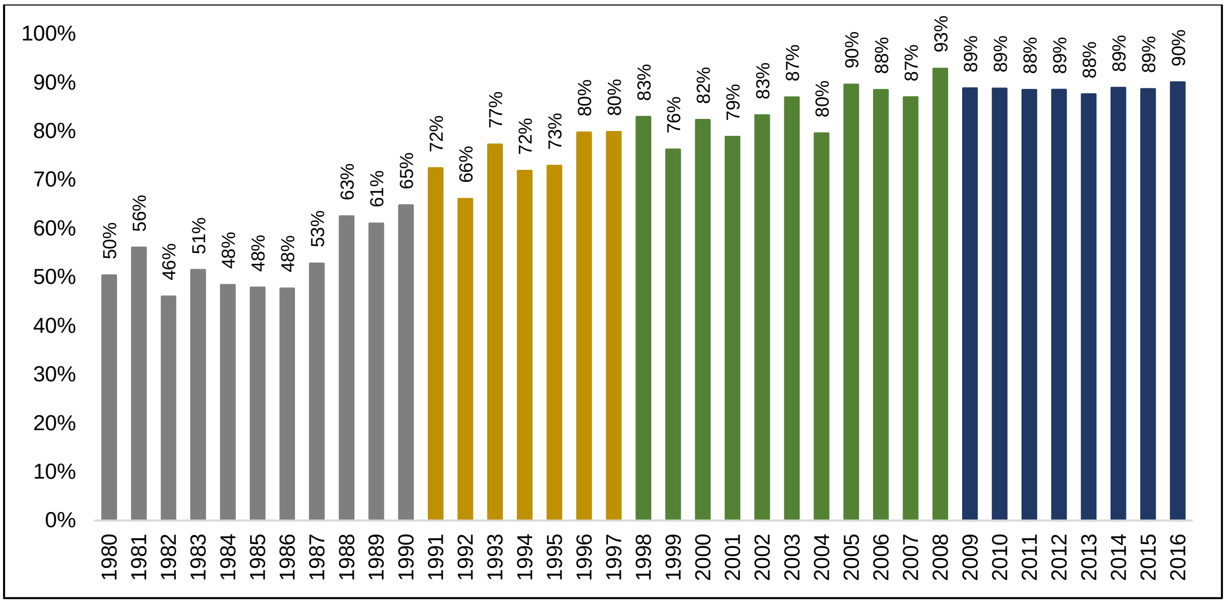

Figure 6.11: Annual percentages of co-authored articles in Scopus and WoS for Zimbabwe, 1980-2016 (n=8 468)

It is generally assumed that collaboration varies significantly across time, fields and sectors. Hence, an investigation into the types of research collaboration in six fields across four socio-political periods was undertaken. Table 6.4 below shows a breakdown of the co-authored articles by broad field in the four socio-political periods. Percentages of less than 40% are highlighted to show the fewest instances of collaboration. As mentioned in Chapter 2, the four socio-political periods used in the study were composed of different numbers of years: the first period (1980-1990) comprised 11 years, the second period (1991-1997) comprised seven years, while the third period (1998-2008) comprised 11 years, and the last period (2009-2016) eight years. The focus should therefore not be on the absolute numbers of articles in each period but on the shares of co-authored articles. The objective was to determine whether co-authorship patterns correlated with the changes in the country’s socio-political environment.

Table 6. 4: Summary profile of co-authored articles by field and socio-political period

Field	Total period		Socio-political periods							
			1980-1990		1991-1997		1998-2008		2009-2016	
	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored
Agricultural sciences	2 091	88%	309	63%	450	83%	772	94%	560	98%
Health sciences	4 353	86%	936	64%	898	85%	1 232	91%	1 287	97%
Natural sciences	3 446	81%	487	54%	610	74%	1 117	84%	1 232	93%
Social sciences	1 628	62%	232	30%	281	51%	404	65%	711	75%
Humanities	450	37%	73	18%	44	16%	92	29%	241	50%
Engineering and technologies	453	68%	51	25%	104	58%	187	71%	111	92%

According to Table 6.4, the share of collaborative articles in all fields increased steadily across all four socio-political periods. For both agricultural sciences and health sciences, the first period (1980-1990) already had relatively high levels of co-authorship (63% and 64%, respectively), which further escalated to very close to 100% (98% and 97%, respectively) in the last period (2009-2016). To a slightly lesser degree, the same can also be said of co-authorship in the natural sciences. In both the social sciences and in engineering and technologies, a shift towards collaborative work became more noticeable only in the second period (1991-1997), when each field surpassed the 50% mark (contributions of 51% and 58%, respectively). However, in the humanities, collaboration only became noticeable in the last period (2009-2016), when its share reached the 50% mark. Based on the data in Table 6.3, it can be concluded that the patterns of co-authorship in Zimbabwe were not uniform but field-specific. On the other hand, irrespective of the changes in the country's socio-political climate, co-authorship increased consistently across all fields.

Table 6.5 shows the share of co-authored articles, by field, for the period 2012–2016. The reason again for using this shorter timeframe was that data from the NRDZ were available for this period only. Two sets of data thus underlie the results as seen in the table. The first comprised data from both Scopus and WoS, whereas the second also included article data from the NRDZ. The main reason for the comparative analysis was to determine whether there would be variations in the co-authorship patterns if a local data source (NRDZ) were to be added to the two international data sources (Scopus and WoS).

Table 6.5 shows that the addition of data from the NRDZ had little effect on the representation of co-authored articles in the six fields, with the exception of marginal differences in each of the natural sciences, social sciences and humanities. For instance, between 2012 and 2016, 46% of humanities articles indexed in Scopus, WoS and the NRDZ were co-authored. When the NRDZ was excluded, the percentage of co-authored humanities articles went up slightly to 49%. This means that there were a fair number of single authored humanities articles in the NRDZ; hence the reduced percentage of co-authored articles in the integrated dataset. The same argument applies to the natural sciences and social sciences, as each of these broad fields reported reduced percentages of co-authored articles when data from the NRDZ were included.

Table 6. 5: Comparative profile of co-authored articles by field for the period 2012-2016

Field	Scopus & WoS		Scopus, WoS & NRDZ	
	All articles	% co-authored	All articles	% co-authored
Agricultural sciences	398	98%	401	98%
Health sciences	918	97%	947	97%
Natural sciences	905	93%	1 033	89%
Social sciences	550	77%	637	74%
Humanities	180	49%	210	46%
Engineering and technologies	87	93%	88	93%

The focus now shifts to the percentage breakdown of co-authored articles, by sector, in each of the four socio-political periods (Table 6.6). It is shown that the share of collaborative articles in the five sectors increased steadily throughout the study period. The government, NGO and INO sectors approached 100% in the last period, each respectively producing 96%, 97% and 98% co-authored articles. Overall, between 1980 and 2016, the university sector had the smallest percentage of co-authored articles (79% out of 7 131 articles). The university sector produced the smallest share of co-authored articles in the most recent period (88% for 2009–2016), indicating that the university sector produced the largest share of single-authored articles in the period under review, both overall and lately (21% overall and 12% in the last period).

Table 6. 6: Profile of co-authored articles by national sector and socio-political period

Sector	Total period		1980-1990		1991-1997		1998-2008		2009-2016	
	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored	All articles	% co-authored
University	7 131	79%	1 138	54%	1 316	77%	2 163	85%	2 514	88%
Government	2 534	81%	624	61%	574	79%	692	88%	644	96%
NGO	646	91%	26	54%	45	80%	189	85%	386	97%
INO	1 193	91%	62	71%	129	76%	448	89%	554	98%
Other	445	80%	44	45%	58	57%	132	83%	211	91%

What follows in Table 6.7 is an analysis of the representation of sector co-authored articles in two datasets – one comprising articles from Scopus, WoS and the NRDZ sources; the other comprising WoS and Scopus articles only. The university sector was found to be the only sector which showed any variation (in terms of percentage shares) when a third data source was used. Based on Scopus and WoS, the share of collaborative articles produced by the university sector between 2012 and 2016 was 87%. When the NRDZ was added as a third data source, the share of co-authored articles decreased slightly to 84%. As before, an obvious explanation is that the NRDZ includes some additional articles that are singularly authored by university authors, and which are not captured in either Scopus or WoS. Table 6.7 also shows that the government, NGO and INO sectors are almost exclusively reliant on co-authorship for their knowledge production. It further shows that additional data from the NRDZ do not really change the respective shares of co-authorship in the different national sectors.

Table 6. 7: Comparative profile of co-authored articles by national sector for the period 2012-2016

Sector	Scopus & WoS		Scopus, WoS & NRDZ	
	All articles	% co-authored	All articles	% co-authored
University	1 894	87%	2 166	84%
Government	493	96%	514	96%
NGO	271	99%	274	99%
INO	409	98%	415	98%
Other	163	91%	164	91%

6.4 Types of research collaboration in Zimbabwe, 1980-2016

The previous section focused on instances of co-authorship more generally but not on the nature or type of co-authorship. This section shows the types of collaboration in which Zimbabwean researchers participate. For the purpose of this analysis, collaboration was broken into three broad types: (i) national collaboration only, (ii) international collaboration only, and (iii) both national and international collaboration.

Figure 6.12 provides an overview of the types of collaboration in the four socio-political periods. Out of a total of 8 460 co-authored articles produced between 1980 and 2016, the majority 3 596 (43%) were generated through international co-authorship only (this refers to articles with two or more international author addresses, in addition to one Zimbabwean author address). A further 2 996 (35%) involved national co-authorship only, while 1 868 (22%)

involved both national and international co-authorship. Articles produced solely through national co-authorship decreased steadily from 72% to 23% over the four periods. On the other hand, a steady increase is observed for articles involving international co-authorship only: from 24% to 52% between periods one and three, where after the figure dropped to 42% in the last period. Articles involving both national and international co-authorship consistently increased from 4% to 35%. These results demonstrate how, with time, researchers in Zimbabwe began to collaborate more with researchers from outside the country.

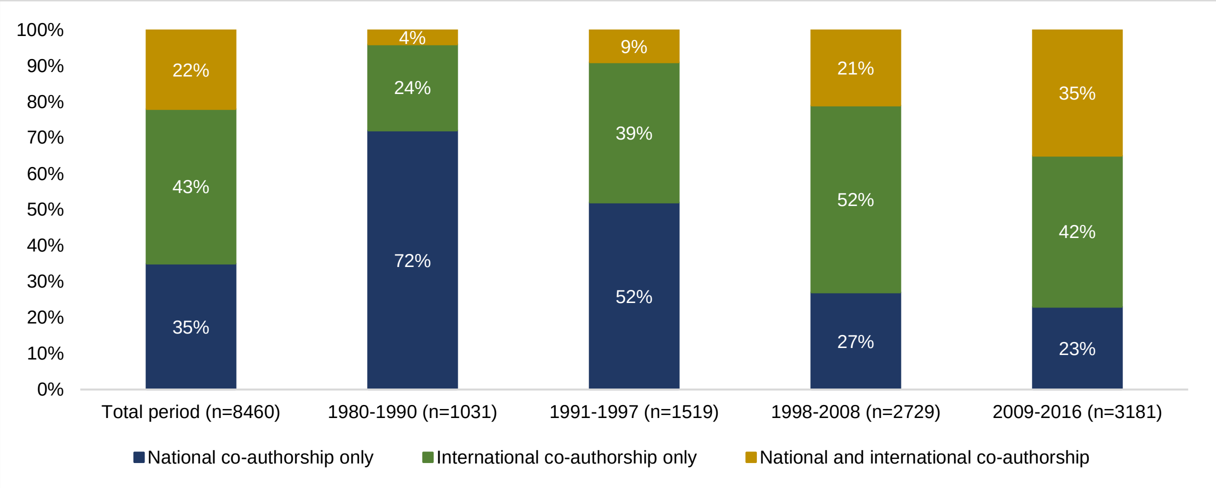

Figure 6.12: National and/or international research collaboration in Zimbabwe in four socio-political periods

Note: Out of a total of 8 468 co-authored articles, eight were excluded from the underlying analysis as they did not have author addresses.

An analysis of research collaboration in Zimbabwe in six broad fields was perfomed. The results of the analysis are illustrated in Appendix 2. It can be seen, as shown in the Appendix that the share of nationally co-authored articles produced in the health sciences decreased systematically (from 80% in 1980-1990 to 13% in 2009-2016), while the share of articles that are both nationally and internationally co-authored increased (from 3% to 46%). Although national co-authorship remained visible in the health sciences across the four periods, there was a clear shift in the type of national co-authorship: fewer solely national co-authorship and more national co-authorship combined with international co-authorship.

Appendix 2 also shows that Agricultural sciences and natural sciences experienced a shift in the type of national co-authorship, from fewer solely national co-authorship to more national co-authorship combined with international co-authorship. For example, in 1980-1990, 65% of articles in the agricultural sciences involved national authorship, a figure that decreased marginally to 63% in 2009-2016. However, in 1980-1990 the relevant figure (65%) was composed of 60% national co-authorship only and 5% national co-authorship combined with international co-authorship. In 2009-2016, the corresponding figure of 63% was composed of only 31% of national co-authorship only.

Figure 6.13 presents an extract from Appendix 2 and shows the relation between research collaboration (national and international) and broad field for the period 2009-2016. As can be seen, in all the six fields, the majority of articles produced involved international co-authorship. For example, 85% of articles in health sciences involved international co-authorship. Of these, 41% were produced through international co-authorship only and the remaining 46% were generated through international co-authorship combined with national co-authorship.

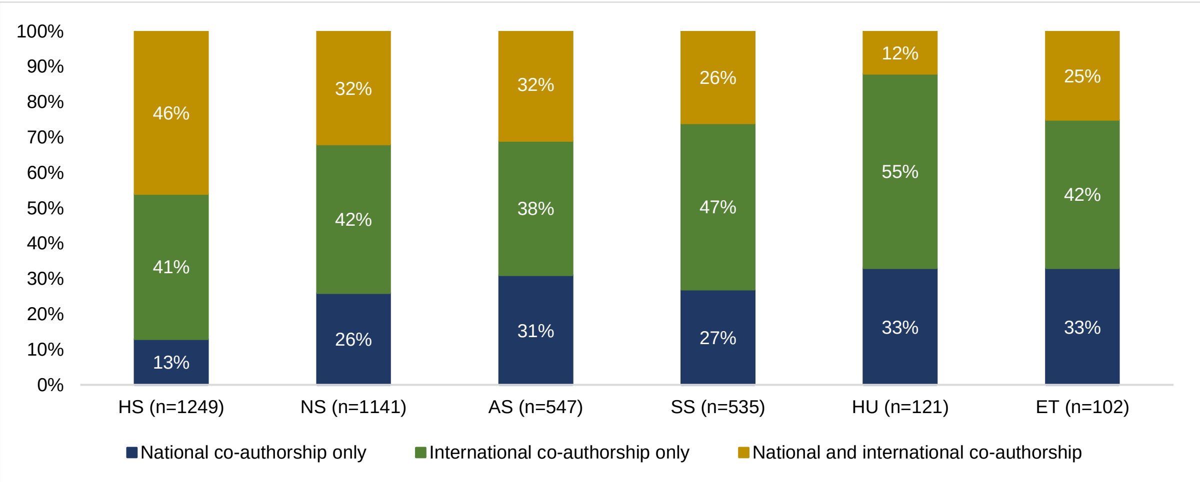

Figure 6. 13: National and/or international research collaboration in Zimbabwe by broad field, 2009-2016

Figure 6.14 shows the types of collaboration (national and/or international) by the five national sectors in the country, for the period 2009-2016. The figure shows that the majority of articles produced by the five sectors between 2009 and 2016 involved international co-authorship. For example, 94% of articles produced by the NGO sector had some form of international co-authorship. Twenty eight percent involved international co-authorship only, while the remaining 66% were generated through combined international and national co-authorship. As compared to other sectors in the country, the university sector had the highest share of articles produced solely through national co-authorship (31%). However, an anlysis of the national sectors across the socio-political periods shows a trend where in each sector, the share of articles produced through national co-authorship alone decreased with time while those involving both national and international co-authorship had increased (see Appendix 3).

For example, when only the government sector is analysed, it is shown can in the Appendix that government sector, the share of articles produced through both national and international co-authorship significantly increased (from 3% in 1980-1990 to 53% in 2009-2016), while articles produced solely through national co-authorship decreased (from 71% to 22%).

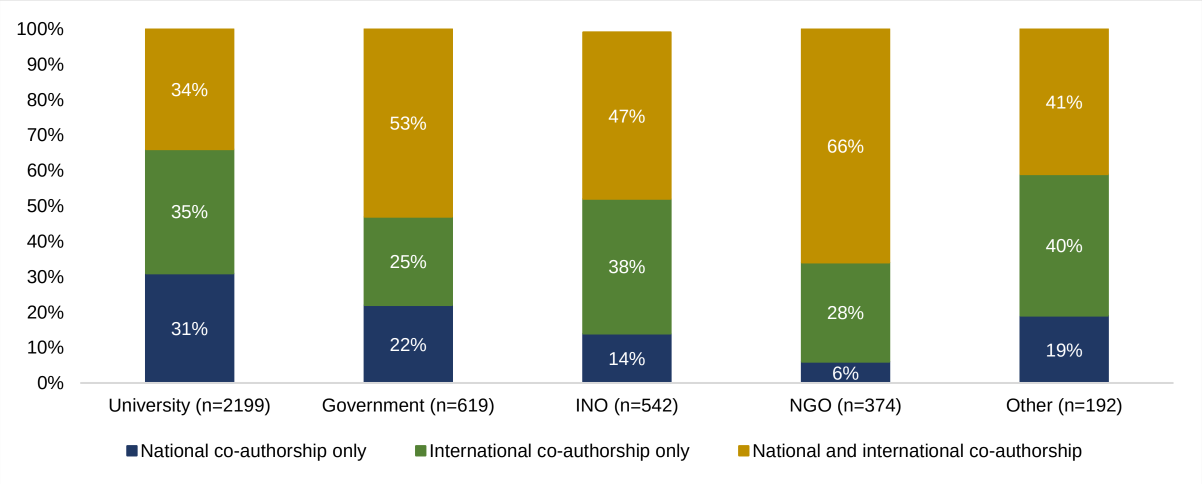

Figure 6. 14: National and/or international research collaboration in Zimbabwe by national sector, 2009-2016

6.4.1 National collaboration in Zimbabwe

National collaboration was broken down into three categories: (i) collaboration within national institutions only – intra-institutional collaboration, (ii) collaboration between national institutions only – inter-institutional collaboration, and (iii) collaboration both between and within national institutions – both intra- and inter-institutional collaboration. Out of a total of 8 460 co-authored articles produced by researchers in Zimbabwe between 1980 and 2016, 4 864 involved national collaboration. Of this total, 2 996 (68%) were generated through intra-institutional collaboration only, while 1 868 (18%) involved both national and international collaboration. These figures are reflected in Figure 6.15 below, which shows an analysis of the forms of national collaboration in Zimbabwe, by socio-political periods. The figure shows that the number of co-authored articles produced through intra-institutional collaboration decreased from 92% in the first period to 56% in the last period. Co-authored articles generated through inter-institutional collaboration increased significantly from 6% in the first period to 25% in the third period and then dropped to 12% in the last. Both intra- and inter-institutional co-authorship grew consistently from 2% to 33% in the period under study. These results indicate that the patterns of national collaboration changed over time. Researchers steadily shifted from collaborating within their own institutions only to also collaborating with other institutions in the country.

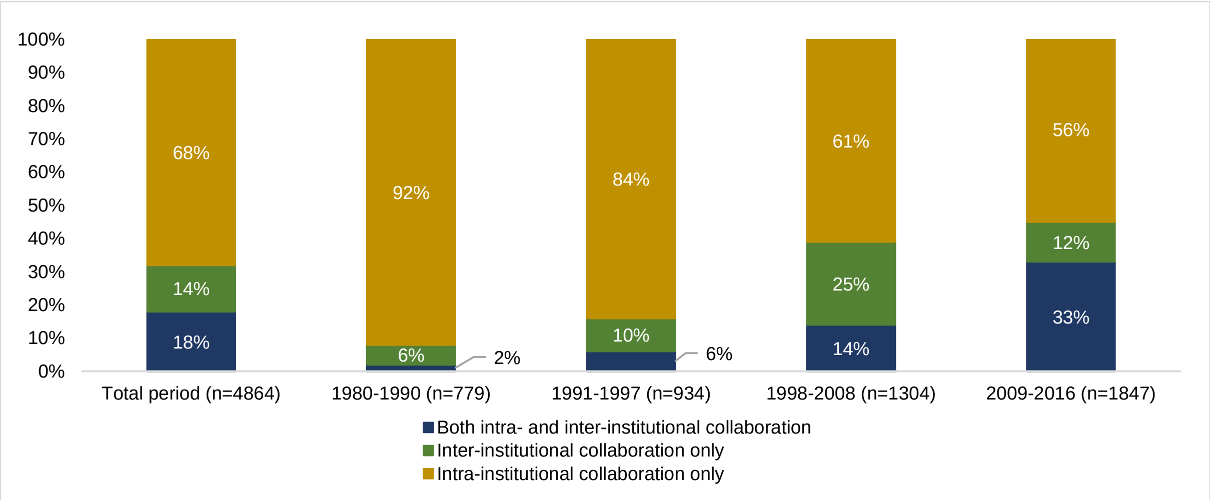

Figure 6. 15 : Summary profile of national collaboration in Zimbabwe by socio-political period

A breakdown of the three types of national collaboration by broad field, across the socio-political periods is provided in Appendix 4. The Appendix illustrates that the majority of nationally co-authored articles in the first period involved intra-institutional collaboration. For instance, in the health sciences in the period 1980-1990, 94% of all nationally co-authored articles were produced by researchers collaborating with academics and scientists within their own institution only. The corresponding figure for the social sciences in the same period was 96%, and 100% each for the humanities and engineering and technologies. However, these figures changed significantly with time as researchers began co-authoring their articles with researchers at other national institutions as well. In the last period, 36% of nationally co-authored articles in the agricultural sciences, 35% of such articles in the natural sciences, and 36% of such articles in the health sciences involved both intra- and inter-institutional collaboration (see Figure 6.16).

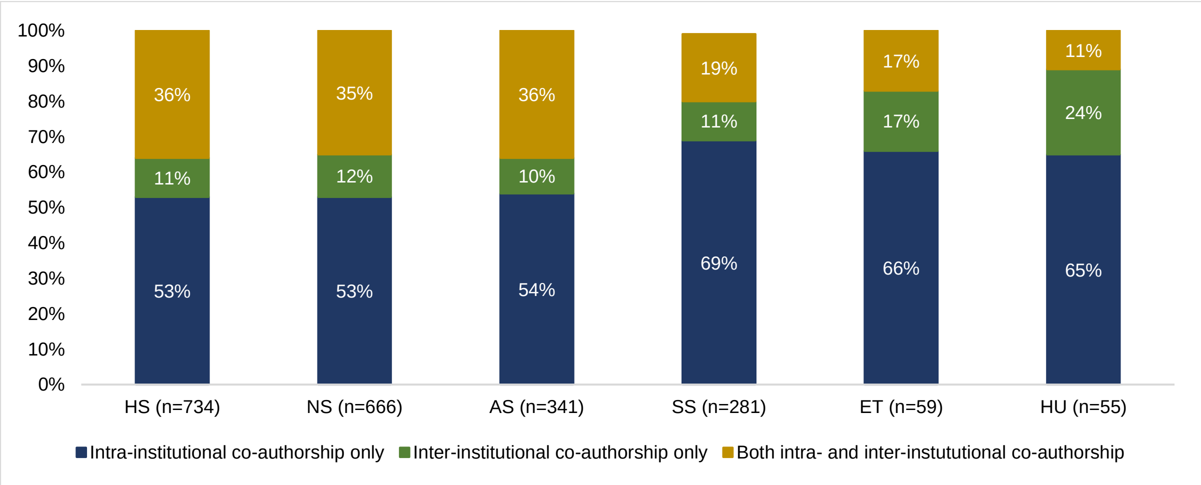

Figure 6. 16: National collaboration in Zimbabwe by broad field, 2009-2012

An analysis of the forms of national collaboration by sectors is provided in Appendix 5. The appendix shows that intra-institutional collaboration decreased with time while co-authorship between and within institutions increased. For instance, the proportional share of nationally co-authored articles produced by the government sector through intra-institutional co-authorship decreased from 84% in the first period to 11% in the last. On the other hand, the sector's share of articles produced through combined intra- and inter-institutional co-authorship increased from 4% in the first to 68% in the last period.

Figure 6.17 confines the analysis to the last period only (2009-2016). It shows that the forms of co-authorship varied across sectors. For instance, only 11% of nationally co-authored articles by the government sector involved intra-institutional co-authorship, while the majority of nationally co-authored articles by the university sector (54%) reflected this type of authorship. These results indicate that researchers in the university sector collaborated largely collaborated within their own institutions, while those in the government sector collaborated mostly with other institutions in the country.

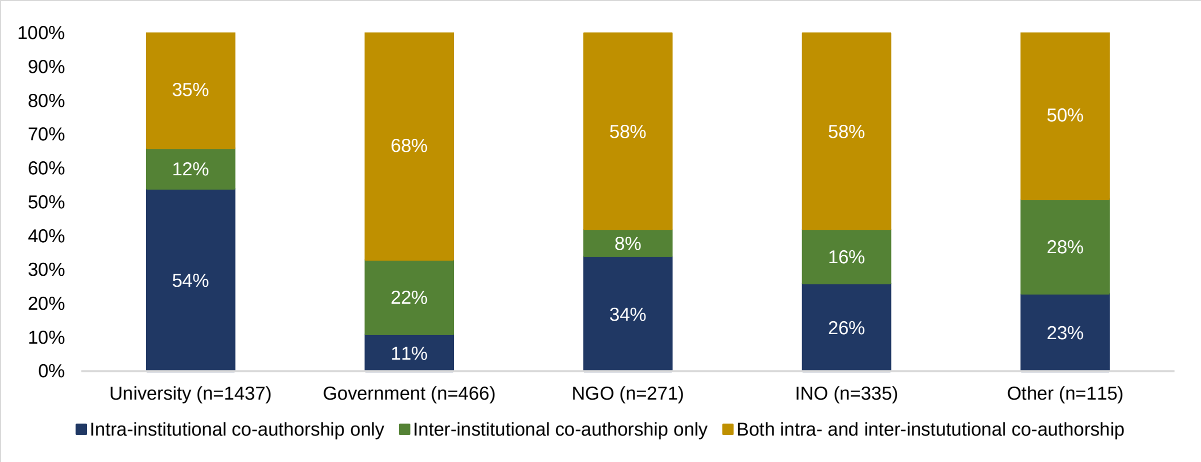

Figure 6. 17: National collaboration in Zimbabwe by national sector, 2009-2016

6.4.2 International collaboration by Zimbabwean authors

The focus now shifts to international collaboration. Firstly, an analysis of the mean number of international authors per article over the period under review was made. Figure 6.18 shows the annual average number of international country mentions per article. It shows that most of the Zimbabwean articles produced between 1980 and 2002, had at least two international country mentions. What this means is that most articles produced in the country had at least two international authors, as indicated by their country affiliations. From 2007 onwards, the average number of international country mentions per article per year increased steadily, reaching an average of 12 country mentions in 2016.

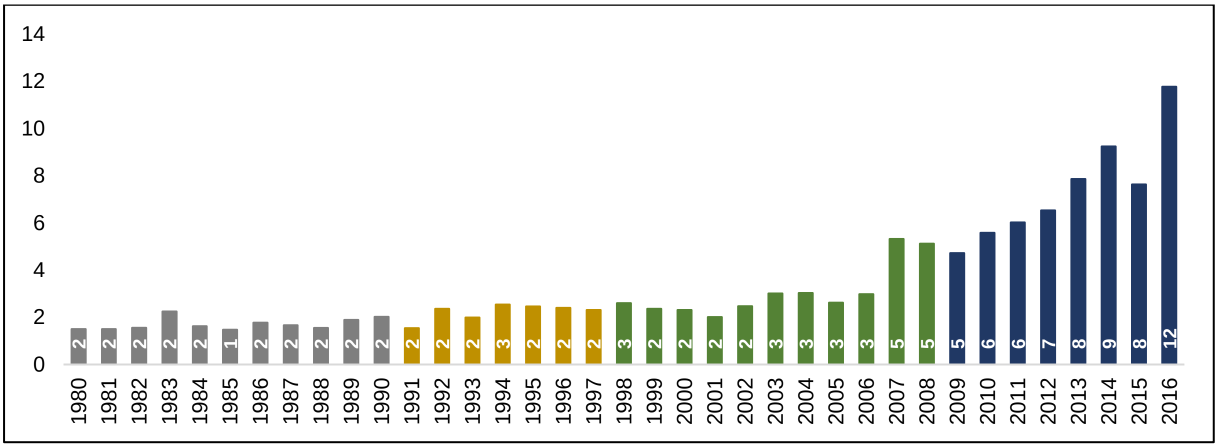

Figure 6. 18: Average number of international countries of authors listed on articles in per year

Table 6.18 shows a breakdown of the average number of international country mentions per article, by broad field in four socio-political periods. The table shows that, with the exception of the fields of the humanities and social sciences, the mean number of international country mentions per article increased with time in four fields (agricultural sciences, engineering and technologies, health sciences, and natural sciences). For example, the average number of international counties listed in papers in the natural sciences increased from two in the first period to seven in the last (in other words, by the last period, the natural sciences articles had an average of seven international authors in an article). Both the health and natural sciences had articles produced by a large number of international authors (793 and 350, respectively). This means the two fields are likely to be involved in large science projects that span across nations.

Table 6. 8: Average number of international article country mentions by broad field in four socio-political periods

Field by period	Average country mentions per article	Standard deviation	Minimum number of authors	Maximum number of authors
AS: 1980-1990 (n=78)	2	0.9	1	5
AS: 1991-1997 (n=180)	2	1.5	1	9
AS: 1998-2008 (n=539)	2	1.5	1	16
AS: 2009-2016 (n=380)	4	3.1	1	23
NS: 1980-1990 (n=121)	2	1.5	1	14
NS: 1991-1997 (n=241)	2	2.3	1	29
NS: 1998-2008 (n=697)	2	2.4	1	22
NS: 2009-2016 (n=845)	7	17.8	1	350
HS: 1980-1990 (n=119)	2	1.3	1	8
HS: 1991-1997 (n=337)	3	3.4	1	29
HS: 1998-2008 (n=825)	4	9.7	1	182
HS: 2009-2016 (n=1 085)	12	39.7	1	793
SS: 1980-1990 (n=232)	2	1.0	1	6
SS: 1991-1997(n=281)	2	2.0	1	19
SS: 1998-2008 (n=404)	4	11.5	1	131
SS: 2009-2016 (n=711)	3	2.9	1	41
HU: 1980-1990 (n=3)	3	3.5	1	7
HU: 1991-1997 (n=5)	9	16.9	1	39
HU: 1998-2008 (n=16)	2	2.2	1	8
HU: 2009-2016 (n=81)	2	3.5	1	28
ET: 1980-1990 (n=6)	2	0.6	1	3
ET: 1991-1997 (n=31)	2	1.0	1	5
ET: 1998-2008 (n=91)	2	1.5	1	10
ET: 2009-2016 (n=68)	3	2.4	1	14

Note: AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

Having presented the mean count of international authors per article over the study period, the focus shifts now to the nature and types of international collaboration. For the purpose of this analysis, collaboration has been grouped into three categories: (i) articles co-authored with researchers in the rest of Africa only (RoA only), (ii) articles co-authored with authors in the rest of the world only (RoW only), and (iii) articles co-authored with authors both in the rest of Africa and the rest of the world (both RoA and RoW). The study found that of a total of 8 460 co-authored articles, 5 464 involved international collaboration. Out of this total, 3 596 involved international co-authorship only, while 1 668 were produced through both international and national co-authorship. Figure 6.19 below shows a summary profile of international collaboration in Zimbabwe by socio-political period.

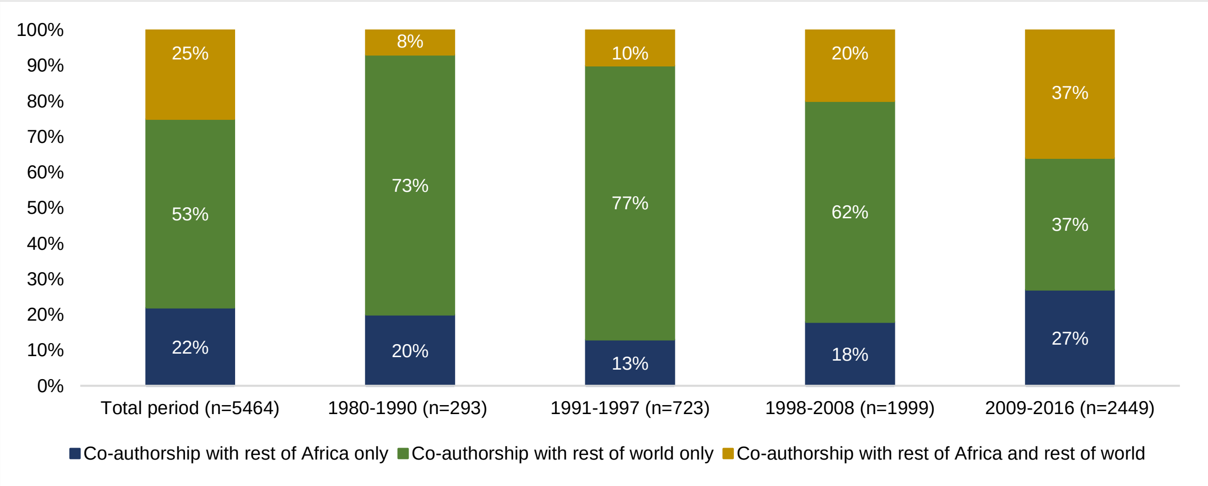

Figure 6.19: Summary profile of international collaboration in Zimbabwe by socio-political period

Figure 6.19 shows that out of a total of 5 464 internationally co-authored articles produced between 1980 and 2016, the majority (53%) involved co-authorship with the rest of the world only (i.e. excluding the rest of Africa). Smaller sets of articles were produced in collaboration with both the rest of Africa and the rest of the world (25%), while 22% involved the rest of Africa only. Articles produced in co-authorship with the rest of the world dramatically decreased from 73% to 37% across the four periods, while those generated through co-authorship on the African continent only increased from 20% in the first period to 27% in the last period, with fluctuations in between. Internationally co-authored articles involving researchers from both the rest of Africa and the rest of the world increased consistently from 8% in the first period to 37% in the last period. From the analysis above, it can be concluded that there was a steady shift in the participation of other countries in Zimbabwe's research. In the early 1980s and 1990s, researchers from the rest of the world contributed the largest share of international co-authorship. However, African participation became more noticeable in the later years, especially in the last two periods.

The most frequently occurring collaborating countries are presented in Table 6.9 below. Contributions of 5% and more are highlighted to show high concentrations of collaboration. It is observed in the table that in the overall period (1980-2016), South Africa emerged as the top international collaborator (19%), followed by the United States (US, 19%), the United Kingdom (UK, 16%) and the Netherlands (5%). The table shows an icrease in the proportion of collaboration between Zimbabwe and South Africa – from 4% in 1980 to 34% in 2016. This perculiar increase could be a reflection of the establishment of new networks between emigrants from Zimbabwe to South Africa. South Africa, the UK and the US constitute approximately 77% of all foreign collaboration in the last period. This dominance could reflect the reality that funding from the UK and the US in fields such as health and agriculture usually involves South Africa, in some cases, it also involves other partner countries in Africa.

Table 6. 9: Contributions of top international collaborating countries by socio-political period

Country	Total period (n=8 460)		1980-1990 (n=1 031)		1991-1997 (n=1 519)		1998-2008 (n=2 729)		2009-2016 (n=3 181)	
	Count	%	Count	%	Count	%	Count	%	Count	%
South Africa	1 592	19%	44	4%	72	5%	396	14%	1 080	34%
US	1 570	19%	70	7%	206	14%	549	20%	745	23%
UK	1 345	16%	84	8%	203	13%	436	16%	622	20%
Netherlands	407	5%	12	1%	38	2%	168	6%	189	6%
France	346	4%	5	<1%	38	2%	103	4%	200	6%
Kenya	344	4%	13	1%	26	2%	121	4%	184	6%
Uganda	249	3%	2	<1%	4	<1%	53	2%	190	6%
Malawi	232	3%	1	<1%	4	<1%	60	2%	167	5%
Zambia	230	3%	4	<1%	12	1%	65	2%	149	5%

Figure 6.20 shows international collaboration in Zimbabwe's research for the period 2009-2016. It shows that international collaboration varied across fields. For example, the social sciences and the humanities had the majority of their internationally co-authored articles produced through collaboration with authors from Africa (47% and 72%, respectively), while the health sciences had the smallest percentage of internationally co-authored articles generated with researchers from Africa only (10%). The bulk of internationally co-authored articles in the health sciences involved co-authorship with both the rest of Africa and the rest

of world (49%), while in the agricultural articles such articles reflect almost equal shares of collaboration with the rest of Africa only (38%), rest of the world only (30%), and rest of Africa and rest of world (32%). For a full illustration of international collaboration in Zimbabwe's research by socio-political periods, see Appendix 6.

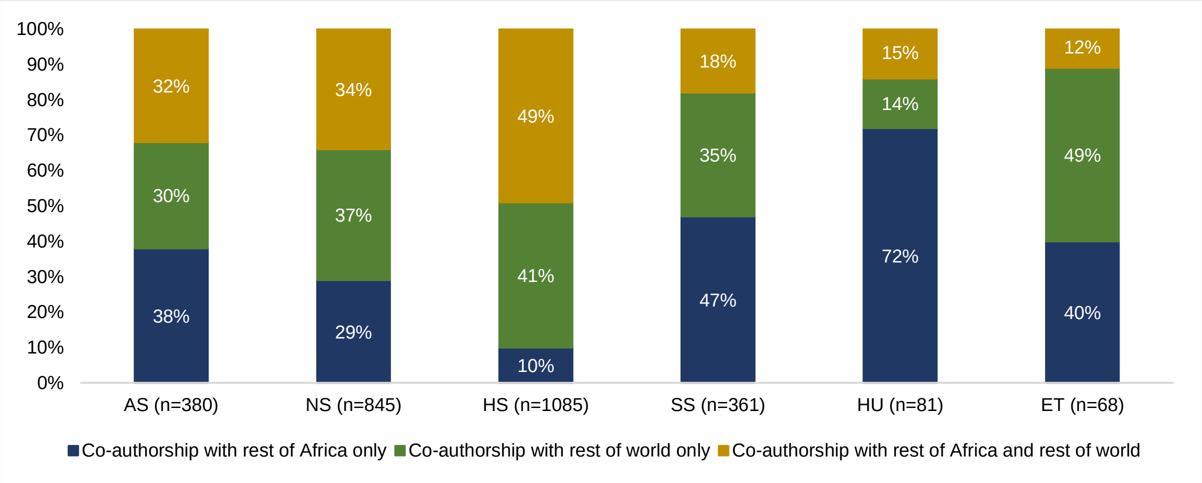

Figure 6. 20: International collaboration in Zimbabwe by broad field, 2009-2016

The top five international collaborators in each field are presented in Table 6.10. It is observed that the US and UK predominantly had a strong presence in the first and second periods in all fields. For instance, between 1991 and 1997, the US was the top contributor of all internationally co-authored articles in agriculture (13%), health (14%) and natural sciences (14%). The UK was the top contributor to social sciences articles (23%) as well as to engineering and technologies articles (25%). South Africa also emerged as a significant contributor, especially in the last period, co-authoring the majority of articles in five fields – with the exception of health sciences where the US still dominated.

Table 6. 10: Top five international collaborating countries by field and socio-political period

	AS	HS	NS	SS	HU	ET
1980-1990	(n=195)	(n=596)	(n=262)	(n=69)	(n=13)	(n=13)
Country 1	US (17; 9%)	UK (44; 7%)	UK (29; 11%)	UK (7; 10%)	AU (2; 15%)	US (2; 15%)
Country 2	AU (13; 7%)	US (28; 5%)	US (28; 11%)	US (4; 6%)	ZM (1; 8%)	UK (1; 8%)
Country 3	UK (12; 6%)	ZA (19; 3%)	ZA (25; 10%)	CA (3; 4%	US (1; 8%)	SE (1; 8%)
Country 4	ZA (10; 5%)	NL (7; 1%)	AU (11; 4%)	ZM (2; 3%)	TZ (1; 8%)	ZA (1; 8%)
Country 5	NL (7; 4%)	KE (7; 1%)	CA (7; 3%)	CH (2; 3%)	NG (1; 8%	PL (1; 8%)
1991-1997	(n=372)	(n=759)	(n=454)	(n=143)	(n=7)	(n=60)
Country 1	US (48; 13%)	USA (104; 14)	US (64; 14%)	UK (33; 23%)	US (3; 43%)	UK (16; 25%)
Country 2	UK (46; 12%)	UK (90; 12)	UK (57; 13%)	US (23; 16%)	UK (2; 29%)	JP (6; 10%)
Country 3	KE (13; 3%)	SE (36; 5)	ZA (32; 7%)	ZA (7; 5%)	ZA (2; 29%)	US (5; 8%)
Country 4	ZA (12; 3%)	ZA (28; 4)	NL (16; 4%)	NO (4; 3%)	ZM (1; 14%)	SZ (2; 3%)
Country 5	NL (10:3%)	DK (22; 3)	SE (16; 4%)	SE (4; 3%)	UG (1; 14%)	ZA (2; 3%)
1998-2008	(n=726)	(n=1125)	(n=938)	(n=264)	(n=27)	(n=133)
Country 1	US (113; 16%)	US (312; 28)	ZA (172; 18%)	US (78; 30%)	US (5; 19%)	ZA (25; 19%)
Country 2	ZA (104; 14%)	UK (208; 18)	US (146; 16%)	UK (65; 25%)	ZA (4; 15%)	UK (21; 16%)
Country 3	UK (89; 12%)	ZA (108; 10)	UK (136; 14%)	ZA (35; 13%)	UK (3; 11%)	SE (14; 11%)
Country 4	KE (54; 7%)	CH (67; 6)	NL (69; 7%)	CA (24; 9%)	TZ (1; 4%)	US (10; 8%)
Country 5	NL (49; 7%)	DK (60; 5)	DE (46; 5%)	NL (21; 8%)	CH (1; 4%)	AU (7; 5%)
2009-2016	(n=547)	(n=1250)	(n=1142)	(n=535)	(n=121)	(n=102)
Country 1	ZA (157; 29%)	US (520; 42%)	ZA (384; 34%)	ZA (207; 39%)	ZA (62; 51%)	ZA (28; 27%)
Country 2	KE (62; 11%)	ZA (416; 33%)	US (207; 18%)	US (82; 15%)	US (9; 7%)	NL (10; 10%)
Country 3	NL (56; 10%)	UK (402; 32%)	UK (193; 17%)	UK (76; 14%)	UK (9; 7%)	CN (8; 8%)
Country 4	US (46; 8%)	UG (154; 12%)	FR (105; 9%)	NL (14; 3%)	BW (4; 3%)	US (5; 5%)
Country 5	UK (33; 6%)	MW (115; 9%)	NL (93; 8%)	MW (14; 3%)	MW (3; 2%)	UK (5; 5%)

Notes:

AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

AU=Australia; BW=Botswana; CA=Canada; CN=China; DK=Denmark; FR=France; DE=Germany; JP=Japan; KE=Kenya; PL=Poland; MW=Malawi; NL=Netherlands; NG=Nigeria; NO=Norway; ZA=South Africa; SZ=Swaziland; CH=Switzerland; SE=Sweden; TZ=Tanzania; UG=Uganda; UK=United Kingdom; US=United States of America; ZM=Zambia

Figure 6.21 shows the participation of international collaborators in Zimbabwe's research between the period 2009 and 2016. The figure shows that international collaboration varied across sectors. The NGO sector recorded the lowest share of articles produced with authors (9%) from the rest of Africa, and the highest share of articles (63%) produced with authors from the rest of the world only. The university sector on the other hand, produced articles through almost equal shares of collaboration with the rest of Africa only (33%), rest of the world only (35%), and rest of Africa and rest of world (32%). Appendix 7 provides a detailed anlysis of international collaboration in Zimbabwe by national sector and by socio-political periods.

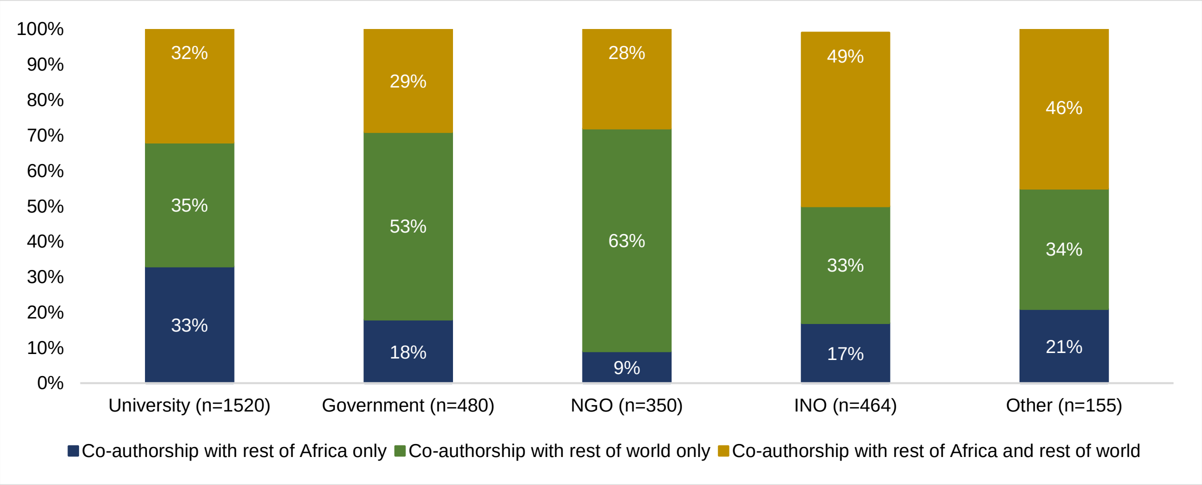

Figure 6. 21: International collaboration in Zimbabwe by national sector, 2009-2016

The top five international contributors to each sector are provided in Table 6.11. The table shows that the US and the UK were the top international collaborators during the first period. This could be the case because of the colonial ties Zimbabwe has with the UK, and because of US institutions such as USAID operating in the country. However, the top international collaborating country was found to be South Africa. The reason for South Africa dominating the last period could be the result of Zimbabwean researchers studying in South Africa. It is generally assumed that when researchers study abroad, they tend to maintain their overseas research groups and research partners, even after returning to their home country. Table 2.12 in Chapter 2 shows that for the year 2017, out of a total of 19 104 students studying abroad, 11 247 (59%) were studying in South Africa.

Table 6. 11: Top five international collaborating countries by national sector and socio-political period

	University	Government	INO	NGO	Other
1980-1990	(n=614)	(n=381)	(n=44)	(n=14)	(n=20)
Country 1	UK (44; 7%)	UK (37; 10%)	US (14; 32%)	US (2; 14%)	NA (2; 10%)
Country 2	US (41; 7%)	ZA (22; 6%)	CA (3; 7%)	UK (2; 14%)	UK (1; 5%)
Country 3	ZA (17; 3%)	US (16; 4%)	UK (2; 5%)	ZA (2; 14%)	ZA (1; 5%)
Country 4	CA (10; 2%)	AU (11; 3%)	JP (2; 5%)	UG (1; 7%)	
Country 5	IT (9; 1%)	CA (7; 2%)	ZM (1; 2%)	IE (1; 7%)	
1991-1997	(n=1009)	(n=456)	(n=98)	(n=36)	(n=33)
Country 1	US (131; 13%)	UK (67; 15%)	US (28; 29%)	US (9; 25%)	US (7; 21%)
Country 2	UK (125; 12%)	US 44; 10%)	UK (10; 10%)	UK (6; 17%)	UK (7; 21%)
Country 3	SE (45; 4%)	ZA (27; 6%)	KE (8; 8%)	ZA (3; 8%)	ZA (6; 18%)
Country 4	ZA (35; 3%)	DK (21; 5%)	ZA (6; 6%)	FR (2; 6%)	
Country 5	NL (28; 3%)	CH (14; 3)	JA (5; 5%)	CA (2; 6%)	
1998-2008	(n=1842)	(n=609)	(n=399)	(n=161)	(n=110)
Country 1	US (325; 18%)	UK (312:28)	US (112; 28%)	UK (71; 44%)	ZA (24; 22%)
Country 2	ZA (261; 14%)	US (208:18)	KE (50; 13%)	US (36; 22%)	US (22; 20%)
Country 3	UK (237; 13%)	ZA (108:10)	ZA (48; 12%)	ZA (31; 19%)	UK (10; 9%)
Country 4	NL (124; 7%)	CH (67:6)	UK (47; 12%)	DK (12; 7%)	SE (8; 7%)
Country 5	SW (81; 4%)	DK (60:5)	CH (43; 11%)	FR (12; 7%)	KE (7; 6%)
2009-2016	(n=2201)	(n=619)	(n=1142)	(n=374)	(n=192)
Country 1	ZA (748; 34%)	ZA (164; 26%)	US (158; 29%)	UK (213; 57%)	ZA (91; 47%)
Country 2	US (424; 19%)	US (151; 24%)	ZA (137; 25%)	US (148; 40%)	US (58; 30%)
Country 3	UK (320; 15%)	FR (81; 13%)	UK (100; 18%)	ZA (99; 26%)	UK (39; 20%)
Country 4	UG (114; 5%)	NL (32; 5%)	FR (79; 15%)	UG (27; 7%)	ZM (32; 17%)
Country 5	NL (110; 5%)		KE (74; 14%)	ZM (18; 5%)	CH (25; 13%)

Note: AU=Australia; BW=Botswana; CA=Canada; CN=China; DK=Denmark; FR=France; DE=Germany; JP=Japan; KE=Kenya; PL=Poland; MW=Malawi; NL=Netherlands; NG=Nigeria; NO=Norway; ZA=South Africa; SZ=Swaziland; CH=Switzerland; SE=Sweden; TZ=Tanzania; UG=Uganda; UK=United Kingdom; US=United States of America; ZM=Zambia

6.5 Summary profile of all co-authored articles in Zimbabwe

Finally, a summary profile of all co-authored articles in Zimbabwe was made. It is noted that one cannot only view the different sub-types of national and international collaboration in isolation because the one also includes elements of the other, and vice versa. To this end, a summary profile of all co-authored articles in Zimbabwe was compiled. For the purpose of the summary, two sets of collaboration types had to be created. Each set comprised seven mutually exclusive categories:

Set 1 (viewed through the lens of national collaboration):

- National collaboration together with international collaboration with rest of Africa only
- National collaboration together with international collaboration with rest of world only
- National collaboration together with international collaboration with both rest of Africa and rest of world
- National collaboration together with no international collaboration
- No national collaboration but international collaboration with rest of Africa only
- No national collaboration but international collaboration with rest of world only
- No national collaboration but international collaboration with both rest of Africa and rest of world.

Set 2 (viewed through the lens of international collaboration):

- International collaboration together with intra-institutional collaboration only
- International collaboration together with inter-institutional collaboration only
- International collaboration together with both intra- and inter-institutional collaboration
- International collaboration together with no national collaboration
- No international collaboration but intra-institutional collaboration only
- No international collaboration but inter-institutional collaboration only
- No international collaboration but both intra- and inter-institutional collaboration

The two sets of categories were subsequently analysed in terms of the four socio-political periods, six broad fields and five broad sectors. Presented first in Table 6.12 is a summary of the analyses for national co-authored articles (set 1 above). The corresponding summary for internationally co-authored articles (set 2 above) appears in Table 6.13. Cells with percentages of 20% and above are highlighted in order to show concentrations of collaboration.

Table 6.12 shows that out of a total of 8 460 co-authored articles produced between 1980 and 2016, 35% were produced through national collaboration without any form of international collaboration. A slightly smaller percentage (22%) involved international collaboration with the rest of the world only, without any form of national collaboration. An additional 13% involved national collaboration together with international collaboration with the rest of the world only.

Broken down by socio-political periods, it can be seen that in the first and second periods most articles were produced through national collaboration with less international involvement. For example, out of a total of 1 031 articles generated during the first period, 72% involved national collaboration only without any form of international collaboration. A markedly small percentage of 17% involved international collaboration with the rest of the world without any form of national collaboration. However, in the third and last periods a number of articles involving international co-authorship were recorded. For example, out of a total of 2 729 articles produced during the third period, 31% involved international collaboration without any form of national collaboration, while 27% involved national collaboration without any form of international collaboration.

When co-authorship is disaggregated by broad field, it can be observed that the majority of co-authored articles were produced through national collaboration only, or through international collaboration only without any form of national collaboration. For example, out of a total of 2 795 co-authored articles in the natural sciences, 32% were generated through national collaboration without any form of international involvement, while 25% had no national collaboration but involved international collaboration with the rest of the world. An additional 11% also had no national collaboration but were produced through international collaboration with the rest of Africa only. From analysing the country's sectors, it can be seen that, with the exception of the NGO sector, the majority of articles were nationally co-authored with less international involvement. For instance, out of the 5 663 articles produced by the university sector, 41% had no international involvement but were generated through national collaboration. However, a total share of 18% was produced without any form of national collaboration but through international collaboration with the rest of the world.

Table 6. 12: Summary profile of all internationally co-authored articles in Zimbabwe

	National collaboration together with				No national collaboration but		
	International collaboration with rest of Africa only	International collaboration with rest of world only	International collaboration with both rest of Africa and rest of world	No international collaboration	International collaboration with rest of Africa only	International collaboration with rest of world only	International collaboration with both rest of Africa and rest of world
All co-authored articles (8 460)	5%	13%	5%	35%	9%	22%	12%
Co-authored articles by period							
1980-1990 (n=1 031)	1%	3%	0%	72%	1%	17%	2%
1991-1997 (n=1 519)	1%	7%	1%	52%	1%	29%	4%
1998-2008 (n=2 729)	4%	15%	3%	27%	4%	31%	12%
2009-2016 (n=3 181)	8%	17%	10%	23%	8%	12%	18%
Co-authored articles by broad field							
Health sciences (n=3 726)	2%	18%	6%	37%	5%	19%	14%
Natural sciences (n=2 795)	5%	11%	5%	32%	11%	25%	11%
Agricultural sciences (n=1 839)	6%	9%	4%	36%	10%	24%	10%
Social sciences (n=1 009)	7%	11%	2%	30%	16%	26%	9%
Humanities (n=167)				37%	31%	14%	8%
Engineering and technologies (n=307)	4%	9%	1%	36%	14%	32%	4%
Co-authored articles by sector							
University (n=5 663)	5%	14%	5%	41%	9%	18%	8%
Government (n=2 063)	5%	19%	5%	40%	6%	20%	6%
NGO (n=585)	11%	42%	11%	11%	4%	14%	13%
INO (n=1 083)	12%	16%	12%	17%	8%	19%	22%
Other (n=354)	7%	15%	10%	27%	9%	14%	16%

The focus shifts now to viewing collaboration from the point of view of international collaboration (see Table 6.13). As will be seen, the results in Table 6.13 are the same as those in Table 6.12. The difference between the two tables is the lens through which collaboration is examined. By way of illustration, Figure 6.12 shows that out of 8 460 co-authored articles produced between 1980 and 2016, 35% were produced through national collaboration without any form of international collaboration. Figure 6.13, on the other hand, shows that out of a total of 8 460 co-authored articles produced in the period under review, 43% involved international collaboration without any form of national collaboration, while 28% intra-institutional collaboration only without any form of international collaboration. Furthermore, 3% involved inter-institutional collaboration only without international collaboration, and 4% involved both intra and inter-institutional collaboration without international involvement. These three percentages of national collaboration without any form of international participation (i.e. 28%, 3%, 4%) together add up to the 35% indicated in column 4 of Table 6.13, which shows national collaboration without any form of international collaboration.

Turning to the results shown in Table 6.13, as can be seen, out of the 8 460 co-authored articles produced between 1980 and 2016, the majority (43%) involved international collaboration only without any form of national collaboration, and a markedly smaller percentage (28%) intra-institutional collaboration only without any form of international collaboration. An additional 11% were generated through international collaboration including national collaboration within institutions.

Broken down by socio-political periods, it is observed that in the first and second periods, the majority of Zimbabwean co-authored articles were generated through intra-institutional collaboration. For example, between 1980 and 1990, the country produced 1 031 co-authored articles. Of this total, 67% involved collaboration within Zimbabwean institutions only without any other form of collaboration, while 24% involved international collaboration only without any form of national collaboration. The tide turned in the third and fourth periods when the majority of articles were produced in collaboration with international partners. Between 2009 and 2016, the country produced 3 181 co-authored articles, 42% of which were produced in collaboration with international partners only, while 14% involved collaboration within Zimbabwean institutions only, and 12% involved international collaboration including both intra and inter-institutional collaboration.

When co-authorship was broken down by broad field, the majority of all co-authored articles were produced in collaboration with international authors only. For instance, out of a total of 1

839 co-authored agricultural articles, 45% involved international collaboration only while 27% involved collaboration within institutions only. From analysing the country's broad sectors, it was also found that the majority of articles were produced through co-authorship with international partners only, however, the extent of international co-authorship varied from one sector to the other. For example, out of a total of 1 083 articles produced by the INO sector, the majority (49%) involved international collaboration only, while 8% involved collaboration intra-institutional collaboration only without any form of both national and international collaboration. However, when the university sector was analysed, it was observed that out of a total of 5 663 articles produced by the sector, 35% were produced through international collaboration only without any other form of collaboration, while 31% involved collaboration within institutions only.

Table 6. 13: Summary profile of all national co-authored articles in Zimbabwe

	International collaboration together with				No international collaboration but		
	Intra-institutional collaboration only	**Inter-institutional collaboration only**	**Both intra and inter-institutional collaboration**	**No national collaboration**	**Intra-institutional collaboration only**	**Inter-institutional collaboration only**	**Both intra and inter-institutional collaboration**
All co-authored articles (8 460)	11%	5%	6%	43%	28%	3%	4%
Co-authored articles by period							
1980-1990 (n=1 031)	2%	1%	1%	24%	67%	3%	1%
1991-1997 (n=1 519)	5%	3%	1%	39%	46%	4%	2%
1998-2008 (n=2 729)	10%	8%	3%	52%	20%	4%	3%
2009-2016 (n=3 181)	18%	5%	12%	42%	14%	2%	7%
Co-authored articles by broad field							
Health sciences (n=3 726)	14%	5%	7%	37%	30%	2%	4%
Natural sciences (n=2 795)	10%	5%	5%	47%	24%	3%	5%
Agricultural sciences (n=1 839)	9%	6%	4%	45%	27%	4%	5%
Social sciences (n=1 009)	11%	3%	5%	50%	25%	3%	3%
Humanities (n=167)	6%	4%	1%	52%	29%	5%	2%
Engineering and technologies (n=307)	7%	6%	1%	50%	28%	5%	3%
Co-authored articles by national sector							
University (n=5 663)	12%	6%	7%	35%	31%	4%	6%
Government (n=2 063)	3%	12%	13%	31%	22%	8%	10%
NGO (n=585)	17%	12%	28%	31%	2%	3%	6%
INO (n=1 083)	8%	10%	16%	49%	8%	4%	6%
Other (n=354)	8%	11%	13%	40%	9%	10%	9%

6.6 Conclusion

Only a brief summary is presented here as the discussion chapter will bring together the different findings in much more detail, and relate the findings to the original research objectives. Having said this, the results in this chapter showed that Zimbabwe's article output increased over the study period (i.e. 1980-2016). In terms of broad fields, the health sciences emerged as the biggest contributor of articles in the country, followed by the natural sciences. The university sector was found to be the most productive research sector in the country. An analysis of the representation of Zimbabwe's articles showed that Scopus has a relatively higher coverage of articles produced by researchers in the country, as compared to WoS. When a third bibliographic data source (NRDZ) was added to reflect on the value of using a national research database as a bibliometric data source, it was found that the NRDZ contributed little in the way of additional articles already indexed in the WoS and Scopus databases.

Research collaboration generally increased over time, regardless of the socio-political challenges that the country went through. Collaboration varied across time, fields and sectors. In terms of national collaboration, during the first and second periods, researchers in the country produced articles through intra-institutional collaboration. However, in the last two periods, researchers were collaborating with others from different institutions. In terms of international collaboration, the study found that in the first two periods, researchers in Zimbabwe collaborated more with countries outside Africa – mostly the US and UK. In the last two periods, researchers in the country began collaborating more with the rest of Africa. South Africa emerged as the top collaborator amongst all African countries.

The next chapter presents a detailed analysis of the trends and patterns of research production and collaboration of individual Zimbabwean organisations in the respective national sectors.

CHAPTER 7

Bibliometric analysis 2: Research production and research collaboration of Zimbabwean organisations in the different national sectors

7.1 Introduction

The previous chapter provided a general overview of research production and research collaboration in Zimbabwe. This chapter supplements the former analysis by presenting detailed bibliometric analyses of the trends and patterns of research production and collaboration of the different Zimbabwean organisations in their respective sectors, and also within the four socio-political periods. The analyses are based mainly on data from the combined Scopus and Web of Science (WoS) databases. Where the National Research Database of Zimbabwe (NRDZ) data are included in the analyses, it is explicitly stated as such. Profiles were compiled for each of six broad fields: (i) agricultural sciences, (ii) engineering and technologies, (iii) health sciences, (iv) humanities, (v) natural sciences, and (vi) social sciences. The results are presented by field, in the order of the volume of their article output, starting with the field with the largest output (health sciences) and ending with the field with the smallest output (humanities). For each field, the reporting structure is the same. Presented first is an analysis of article output by sector, followed by an analysis of the co-authorship patterns of the most productive national sectors. Finally, analyses of article output and co-authorship of the most productive organisations in the sectors are provided.

7.2 Article output in the health sciences in the different national sectors

The article output of the national sectors in health sciences, by socio-political period, is presented in Table 7.1. For each sector in any period, the following four indicators are reported:

- The total number of articles produced by the sector;
- The number of unique (non-duplicate) Zimbabwean organisations responsible for the article output in the sector;
- The average number of articles per Zimbabwean organisation in the sector; and
- The sector’s contribution (percentage share) to the total article output in the relevant period.

It is shown in Table 7.1 that the average number of articles per year, as produced by the different Zimbabwean sectors in the health sciences, increased over time: from an average of 85 articles per year in the first period to an average of 181 articles per year in the last period.

The increase in the article output per year in the last period could be attributed to more Zimbabwean organisations (e.g. universities, local non-governmental organisations [NGOs], and international national organisations [INOs]) emerging to produce research. For instance, in the first period, six local NGOs contributed to the article output compared to 26 in the last period. Similarly, six INOs participated in Zimbabwe's research production in the first period whereas in the last period the corresponding figure was 29.

Table 7.1 further shows that in the first period, out of a total of 936 articles, the majority (66%) were produced by the university sector. This is followed by the government sector with a percentage contribution of 31%. In the third period, 1 232 articles were produced. Of this total, 69% were accounted for by the university sector. The government sector was responsible for 23% of the total articles in the third period, while INOs produced 12% of the total articles.

The three most productive sectors in the last period were, in order of productivity: the university sector (65%), the government (23%), and the local NGO sector (20%). The NGO sector showed a systematic increase in article output over time, starting with only 2% in the first period, to a high percentage contribution of 20% in the last period. The INO sector also showed a steady increase over time, from 1% in the first period to 15% in the last period. The percentage contribution of the government sector remained constant (23%) in the third and fourth periods; however, this figure was lower than the shares reported in the first and second periods (31% and 29%, respectively). Article output for the universities fluctuated between 69% and 65% across the four periods, with the highest share reported for the third period.

Table 7.1 Summary profile of article output in health sciences, by national sector and socio-political period

National sectors	1980–1990 (n=936) [11 years; 85 articles per year]				1991–1997 (n=898) [7 years; 128 articles per year]				1998–2008 (n=1232) [11 years; 112 articles per year]				2009–2016 (n=1287) [8 years; 161 articles per year]			
	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period
University sector	616	1	616	66%	613	2	307	68%	846	6	141	69%	831	8	104	65%
Government sector	287	9	32	31%	261	16	16	29%	283	16	18	23%	301	15	20	23%
NGO sector	18	6	3	2%	28	11	3	3%	113	15	8	9%	256	26	10	20%
INO sector	10	6	2	1%	40	16	3	5%	151	22	7	12%	199	29	4	15%
Inter-governmental organisations	1	1	1	<1%	15	4	4	2%	90	5	18	7%	87	4	22	7%
International NGOs	4	2	2	<1%	9	9	1	1%	27	12	2	2%	71	19	4	6%
International research organisations	5	3	2	1%	17	3	6	2%	38	5	8	3%	48	6	8	4%
International industry/businesses	--	--	--	--	--	--	--	--	--	--	--	--	2	1	2	<1%
Other national sectors	20	13	2	3%	23	13	2	3%	45	22	2	4%	105	24	4	8%
Industry/businesses	1	1	1	<1%	3	2	2	<1%	15	5	3	1%	40	10	4	3%
Private hospitals and clinics	8	5	2	1%	7	3	2	1%	7	4	2	1%	42	6	7	3%
Private schools and training institutes	2	1	2	<1%	1	1	1	<1%	4	3	1	<1%	16	2	8	1%
Mission or faith-based hospitals	9	7	1	1%	11	6	2	1%	19	8	2	2%	6	5	1	<1%
Unions and associations	--	--	--	--	1	1	1	<1%	2	2	1	<1%	1	1	1	<1%

Notes: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the 'unspecified' sector have been excluded.

Table 7.2 incorporates the NRDZ data into the summary profile for the health sciences. The analysis is confined to the period 2012–2016 as this is the only period for which NRDZ data were available. The objective was to determine how the addition of NRDZ data changes the summary profile for the health sciences compared to when only Scopus and WoS data are utilised. From the comparison, it is observed that almost the entire article output of Zimbabwe in health sciences (918 out of 947) were indexed in Scopus and WoS, with the NRDZ accounting for only 29 additional articles. Little, if any, change can therefore be observed when comparing the indicators derived from Scopus and WoS data with the indicators based on all three data sources.

Table 7.2: Comparative profile of article output in health sciences, by national sector in the period 2012–2016

National sectors	***Based on Scopus and WoS (n=918)*** *[5 years; 184 articles per year]*				***Based on Scopus, WoS and NRDZ (n=947)*** *[5years; 189 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	591	8	74	64%	619	9	69	65%
Government sector	234	13	18	25%	239	13	18	25%
NGO sector	170	21	8	19%	170	21	8	18%
INO sector	154	30	5	17%	157	31	5	17%
Inter-governmental organisations	56	4	14	6%	57	4	14	6%
International NGOs	65	18	4	7%	66	19	3	7%
International research organisations	39	6	7	4%	40	6	7	4%
International industry/businesses	2	2	1	<1%	2	2	1	<1%
Other national sectors	79	16	5	9%	80	17	5	8%
Private hospitals and clinics	35	6	6	4%	35	6	6	4%
Private schools and training institutes	13	2	7	1%	13	2	7	1%
Mission or faith-based hospitals	3	2	2	<1%	3	2	2	<1%
Unions and associations	1	1	1	<1%	1	1	1	<1%
Industry/businesses	27	5	5	3%	28	6	5	3%

7.2.1 Co-authorship patterns of the most productive national sectors in health sciences

In this section, the focus shifts to the co-authorship patterns of the three most productive national sectors in health sciences; namely, the university, government, and local NGO sectors. The three sectors are those highlighted in Table 7.2 above. For the purpose of the co-authorship analysis, two new variables were created and subsequently cross-tabulated. Since any article could involve simultaneous co-authorship by any of the three most productive sectors, the first variable classified the three national sectors into the following seven mutually exclusive categories:

1. University sector only
2. Government sector only
3. NGO sector only
4. Both university sector and government sector
5. Both university sector and NGO sector
6. Both government sector and NGO sector
7. All three sectors.

The second variable considered all co-authoring entities outside the three most productive sectors for health, and classified the different entities into the following four mutually exclusive categories:

1. Other national sectors only
2. International sector only
3. Both other national sectors and international sector
4. Neither other national sectors nor international sector.

‘International sector’, as used in the classification above, refers to an international (non-Zimbabwean) author address. Table 7.3 presents the results of the cross-tabulation between the two categorical variables that had been created, thereby showing the concentrations of authorship in each of the four socio-political periods, together with an indication of the nature of such co-authorship. For each period, the cross-tabulation between the two sets of categories produced a set of 28 cells. The count in each cell was expressed as a percentage of the total article output in a period, meaning that the 28 percentages add to 100%. Any percentage share of at least 10% was taken to imply a concentration of authorship.

In the first period (1980–1990), the three most productive Zimbabwean (ZW) sectors in the health sciences were responsible for 895 articles. Of these, 59% were produced by the university sector on its own, without any co-authorship by other national sectors or international organisations. The government sector was responsible for another 25% of articles, also without any collaboration by other national sectors or international organisations. Together, the two sectors (university and government), each producing research on its own, were responsible for 74% of the 895 articles in the first period.

In the second period (1991-1997), the three sectors were responsible for a total of 835 articles. Of these, 41% of the articles were produced by the university sector on its own without any co-authorship by other national sectors or international organisations. However, of importance to note is that the university sector produced 25% of articles in the second period through co-authorship with international organisations. A complete shift in the co-authorship pattern is seen in the last period (2009-2016). During this period, the three sectors produced a total of 1 110 articles. Of these, 43% were produced by the university sector alone in collaboration with international organisations. The NGO sector, in collaboration with international organisations, was responsible for 11% of the total articles. The three concentration points in the last period (highlighted cells) show that the university sector has been able to sustain its research production through international collaboration. Similarly, the local NGO sector also managed to increase its article output in the last period through international collaboration.

Table 7.3: Co-authorship patterns of the three most productive national sectors in health sciences, by socio-political period

Mutually exclusive classification 1: three most productive national sectors	1980–1990 (n=895)				1991–1997 (n=835)				1998–2008 (n=1062)				2009–2016 (n=1110)			
	Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector			
	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector
University sector only	<1%	7%	0%	59%	<1%	25%	<1%	41%	1%	39%	2%	23%	1%	43%	3%	10%
Government sector only	0%	4%	<1%	25%	1%	9%	<1%	16%	<1%	8%	<1%	4%	<1%	7%	2%	1%
NGO sector only	<1%	<1%	0%	1%	0%	1%	0%	<1%	0%	5%	<1%	1%	<1%	11%	1%	<1%
Both university sector and government sector	<1%	<1%	0%	2%	<1%	1%	0%	4%	1%	6%	<1%	4%	1%	5%	1%	3%
Both university sector and NGO sector	0%	1%	0%	0%	0%	<1%	0%	1%	0%	2%	<1%	1%	0%	4%	<1%	<1%
Both government sector and NGO sector	0%	0%	0%	0%	<1%	<1%	0%	<1%	0%	<1%	<1%	0%	<1%	2%	1%	0%
All three sectors	0%	0%	0%	<1%	0%	0%	0%	0%	0%	1%	0%	0%	<1%	2%	1%	0%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following two categories from Table 7.1: ‘INO sector’ and ‘other national sectors’.

7.2.2 Article output of the most productive Zimbabwean organisations in health sciences

The previous section presented an analysis of article output in the health sciences by sector, and the co-authorship patterns of the three most productive sectors in that field. This section presents the article output of the organisations in each of the three productive sectors. Presented first are organisations in the university sector, followed by organisations in the government sector and then the NGO sector. Lastly, the five most productive Zimbabwean organisations in the health sciences, across sectors, are identified and highlighted.

- ***University sector***

According to Table 7.4, between 1980 and 2016, article production in the health sciences was dominated by a single university, namely the University of Zimbabwe. This university accounted for 100% of all health articles in the first and second periods. Although five universities emerged in the third period, their contribution to output in that period was almost non-existent (no more than 1% each). One argument for the low research output by these universities could be that they were still in their infant years as most of them were established in the second decade after the country's independence (see Chapter 2, Section 2.5.2). The University of Zimbabwe maintained its dominant status in the last period, contributing the larger share of articles (90%).

Table 7.4: Article output in health sciences, by university and socio-political period

Zimbabwean universities	1980–1990 (n=616)		1991–1997 (n=613)		1998–2008 (n=846)		2009–2016 (n=831)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	616	100%	611	100%	828	98%	751	90%
National University of Science and Technology	--	--	2	<1%	11	1%	41	5%
Bindura University of Science Education	--	--	--	--	7	1%	24	3%
Midlands State University	--	--	--	--	1	<1%	6	1%
Zimbabwe Open University	--	--	--	--	2	<1%	10	1%
Chinhoyi University of Technology	--	--	--	--	4	<1%	6	1%
Great Zimbabwe University	--	--	--	--	--	--	6	1%
Harare Institute of Technology	--	--	--	--	--	--	3	<1%

Figure 7.1 provides an analysis of the collaboration trends and patterns of the University of Zimbabwe in the field of health sciences. It can be seen in the figure that there was a systematic decrease in the percentage share of articles produced through single authorship (marked as no collaboration) and articles produced through national collaboration only. It can also be seen that there was a significant increase in articles produced through international collaboration only, and through both international collaboration and national collaboration. For example, articles produced through both national and international collaboration grew from 2% in the first period to 47% in the last period, while articles produced through single authorship (no collaboration) dropped from 36% to 3% between the same two periods.

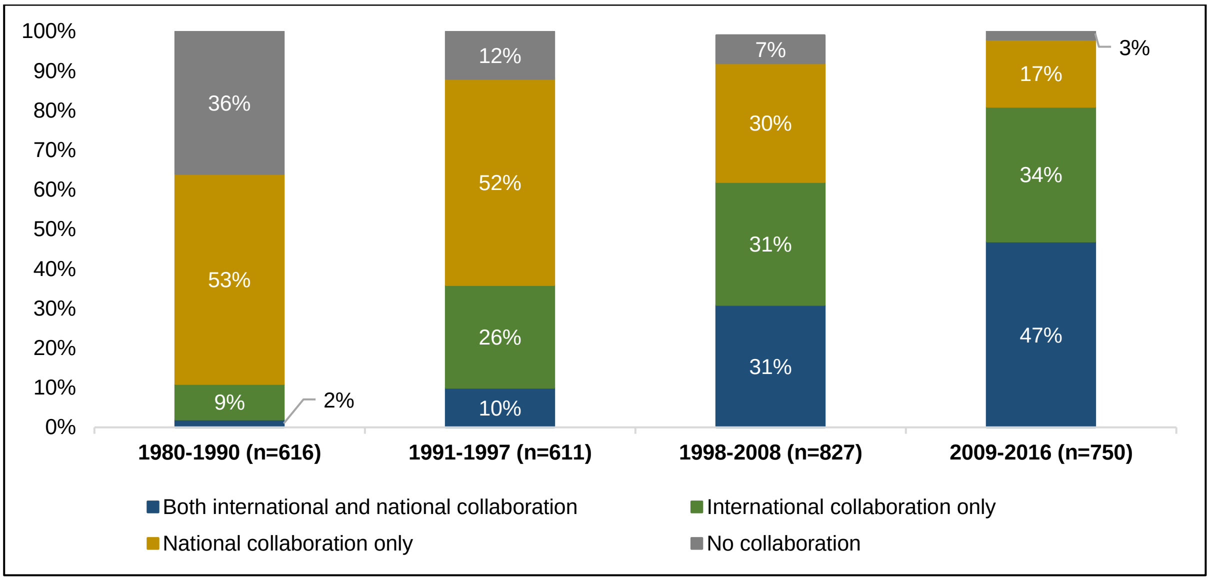

Figure 7.1: National versus international collaboration of the University of Zimbabwe in health sciences, by socio-political period

- ***Government sector***

When analysing the article output from organisations in the government sector (Table 7.5), the Ministry of Health and Child Care emerged as the largest producer of articles in the health sciences (percentages of 78%-83% articles across the four periods). Within the Ministry of Health and Child Care are several organisations (see Appendix 8), which produce articles in health sciences research. As can be seen from Appendix 8, the National Institute of Health Research, formerly known as the Blair Research Institute, was responsible for the bulk of the country’s health research in the first, second and third periods, accounting for 32%, 28% and 39% of output, respectively. The Ministry of Health and Child Care, as a distinct department, accounted for 53% of the article output in the last period.

The output in Table 7.5 also shows that although several government organisations emerged to produce research in the second period, their contribution to the total output was below 20%. The Harare City Council (7%, 5%, 7% and 9%) and the Ministry of Lands, Agriculture and Rural Settlement (11%, 8%, 11% and 4%) both generated sizeable number of articles, respectively, in the review periods.

Table 7.5: Article output in health sciences, by government organisation and socio-political period

Zimbabwean organisations in government sector	1980-1990 (n=287)		1991-1997 (n=261)		1998-2008 (n=283)		2009-2016 (n=249)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Ministry of Health and Child Care	225	78%	209	80%	223	79%	249	83%
Harare City Council	19	7%	13	5%	20	7%	28	9%
Ministry of Lands, Agriculture and Rural Settlement	33	11%	21	8%	32	11%	12	4%
Kadoma City Council	--	--	--	--	--	--	6	2%
Bulawayo City Council	--	--	7	3%	2	1%	4	1%
Ministry of Primary and Secondary Education	--	--	2	1%	--	--	4	1%
Natural History Museum of Zimbabwe	--	--	1	<1%	1	0%	3	1%
Forestry Commission of Zimbabwe - Forest Research Centre	--	--	4	2%	5	2%	3	1%
Ministry of Public Service, Labour and Social Welfare	1	<1%	2	1%	--	--	2	1%
Zimbabwe National Statistics Agency (ZIMSTAT)	--	--	--	--	1	<1%	2	1%
Research Council of Zimbabwe	--	--	--	--	--	--	2	1%
Zimbabwe Parks and Wildlife Management Authority	3	1%	1	0%	--	--	1	<1%
Zimbabwe Prisons and Correctional Service	--	--	--	--	--	--	1	<1%
Scientific and Industrial Research and Development Centre (SIRDC)	--	--	--	--	--	--	1	<1%
Mutero High School	--	--	--	--	--	--	1	<1%
Zimbabwe National Army	--	--	4	2%	1	<1%	--	--
Mutare City Council	--	--	2	1%	1	<1%	--	--
Murewa District Health Services Department	--	--	1	<1%	1	<1%	--	--
Gweru City Council	--	--	1	<1%	1	<1%	--	--
District Medical Office, Bulawayo	--	--	1	<1%	--	--	--	--
Bulawayo Polytechnic College	--	--	1	<1%	--	--	--	--
Chitungwiza City Council	--	--	--	--	2	1%	--	--
Zimbabwe Defence Forces	--		--	--	2	1%	--	--
Pafiwa Secondary School	--	--	--	--	1	<1%	--	--
Seke Teachers College	--	--	--	--	1	<1%	--	--
Tsholotsho District Health Services Department	--	--	--	--	1	<1%	--	--
Zimbabwe Republic Police	3	1%	3	1%	--	--	--	--
Ministry of Local Government, Public Works and National Housing	1	<1%	--	--	--	--	--	--
District Medical Office, Buhera	1	<1%	--	--	--	--	--	--
Bromley Ruwa Rural Council Clinic	1	<1%	--	--	--	--	--	--

Figure 7.2 also shows an analysis of collaboration of the Ministry of Health and Child Care. As can be seen, there was a consistent decrease in the percentage contribution of articles produced through no collaboration and through national collaboration only. For example, articles produced through national collaboration only decreased from 52% in the first period to 14% in the last period. However, articles produced through both international and national collaboration increased consistently over time from 2% to 69%. The bulk of the articles (69%) produced by the Ministry of Health and Child Care in the period 2009-2016 involved both national and international collaboration.

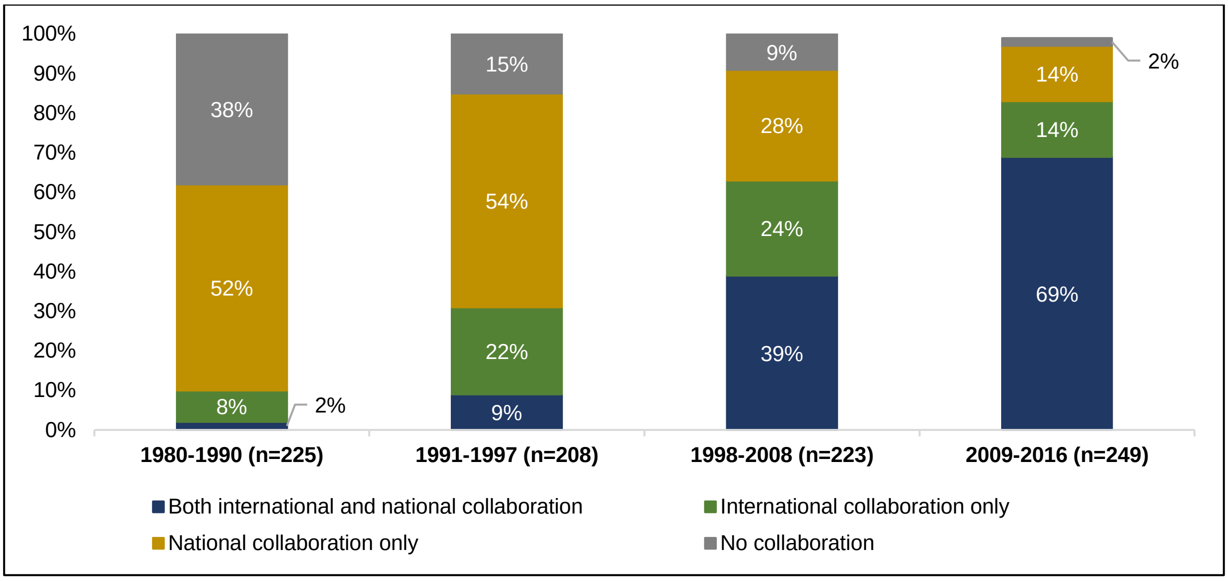

Figure 7.2: National versus international collaboration of the Ministry of Health and Child Care in health sciences, by socio-political period

- ***NGO sector***

An analysis of the article contribution of organisations in the NGO sector (Table 7.6) was also undertaken. The number of NGOs producing health science research increased over time. In the first period, six NGOs produced a total of 18 articles, while in period four, 26 NGOs were responsible for a total of 256 articles. The most productive organisations in the last period were the Biomedical Research and Training Institute (49%) and the Zvitambo project (an organisation for maternal and child health research) at 22%. These were followed by the Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR), with a percentage contribution of 12%. The National Blood Service of Zimbabwe made large contributions in the first (39%) and second (43%) periods, only to drop significantly in the third (6%) and fourth (3%) periods.

Table 7.6: Article output in health sciences, by NGO and socio-political period

Zimbabwean organisations in NGO sector	1980–1990 (n=18)		1991–1997 (n= 28)		1998–2008 (n=113)		2009–2016 (n=256)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Biomedical Research and Training Institute	--	--	4	14%	63	56%	126	49%
Zvitambo	--	--	--	--	21	19%	56	22%
Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR)	--	--	--	--	--	--	31	12%
National Blood Service of Zimbabwe	7	39%	12	43%	7	6%	7	3%
Organisation for Public Health Interventions and Development (OPHID)	--	--	--	--	1	1%	6	2%
Diocese of Mutare Community Care Programme (DOMCCP)	--	--	--	--	--	--	4	2%
Island Hospice Service	1	6%	--	--	1	1%	3	1%
Zichire Project	--	--	--	--	--	--	3	1%
Family AIDS Caring Trust	1	6%	3	11%	6	5%	2	1%
AWARE Trust	--	--	--	--	--	--	2	1%
Victoria Falls Wildlife Trust	--	--	--	--	--	--	2	1%
Training and Research Support Centre (TARSC)	--	--	--	--	--	--	2	1%
Community Working Group on Health	--	--	--	--	--	--	2	1%
Zimbabwe Diabetic Association	--	--	--	--	--	--	2	1%
Malilangwe Wildlife Reserve	--	--	--	--	--	--	2	1%
St Giles Medical Rehabilitation Centre	4	22%	1	4%	1	1%	1	<1%
Hospice and Palliative Care Association of Zimbabwe (HOSPAZ)	--	--	--	--	1	1%	1	<1%
Zimbabwe Red Cross Society	--	--	--	--	--	--	1	<1%
Zimbabwe Environmental Law Association (ZELA)	--	--	--	--	--	--	1	<1%
Counselling Services Unit	--	--	--	--	--	--	1	<1%
African Wildlife Conservation Fund	--	--	--	--	--	--	1	<1%
Zimbabwe Association of Doctors for Human Rights (ZADHR)	--	--	--	--	--	--	1	<1%
Pharmaceutical Society of Zimbabwe	--	--	--	--	--	--	1	<1%
Welthungerhilfe Zimbabwe	--	--	--	--	--	--	1	<1%
Lowveld Rhino Trust	--	--	--	--	--	--	1	<1%
Training and Research Support Centre (TARSC)	--	--	--	--	6	5%	--	--
Epilepsy Support Foundation Zimbabwe	--	--	3	11%	2	2%	--	--
Biodiversity Foundation for Africa	--	--	--	--	2	2%	--	--
Women and AIDS Support Network Zimbabwe (WASN)	--	--	1	4%	1	1%	--	--
SPCA Bulawayo	--	--	--	--	1	1%	--	--
Media support - MISA Zimbabwe	--	--	--	--	1	1%	--	--
Family Support Trust	--	--	--	--	1	1%	--	--
Christian Life Centre	--	--	2	7%	--	--	--	--
Student Christian Movement of Zimbabwe	--	--	1	4%	--	--	--	--
Musasa Project	--	--	1	4%	--	--	--	--
Matabeleland AIDS Council	--	--	1	4%	--	--	--	--
Bulawayo Legal Projects Centre	--	--	1	4%	--	--	--	--
Council for the Blind	4	22%	--	--	--	--	--	--
Zimcare Trust	1	6%	--	--	--	--	--	--

The collaboration patterns of the two most productive organisations in the ZW NGO sector (i.e. the Biomedical Research and Training Institute, and Zvitambo), were explored more closely (Figure 7.3). Here, it is revealed that the two organisations displayed different collaboration trends. For example, the number of articles produced by the Biomedical Research and Training Institute, through international collaboration only, decreased from 48% in the period 1998-2008 to 12% in the period 2009-2016, while the number of articles produced by Zvitambo, also through international collaboration only, increased from 4% to 34%.

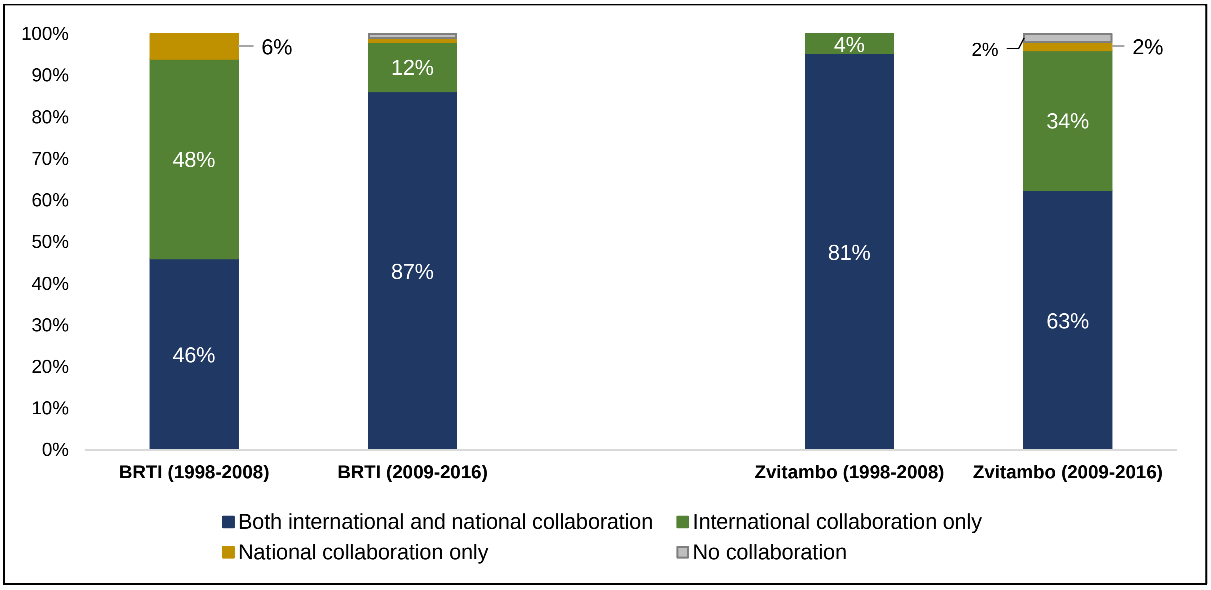

Figure 7.3: National versus international collaboration of the Biomedical Research and Training Institute and Zvitambo, respectively, in health sciences, by socio-political period

- ***The five most research-productive organisations in the health sciences***

Finally, based on Tables 7.4, 7.5 and 7.6, the five most productive Zimbabwean organisations in the last period, across all three productive sectors, could be identified. The five organisations are presented in Table 7.7. The table shows the total number of articles produced by each organisation. The totals are further expressed as a percentage of the total number of articles in Zimbabwe in the last period, and as a percentage of the total number of articles in the sector to which the organisation belongs. Also indicated is what percentage of an organisation's article output involved international co-authorship.

Table 7.7: Summary profile of the five most research-productive organisations in health sciences, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	751	58%	90%	81%
Ministry of Health and Child Care (Government sector)	249	19%	83%	84%
Biomedical Research and Training Institute (NGO sector)	126	14%	49%	98%
Zvitambo (NGO sector)	56	4%	22%	96%
Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR) (NGO sector)	31	2%	12%	100%

Based on Table 7.7, it is observed that between 2009 and 2016, the University of Zimbabwe, with a percentage contribution of 58%, produced the majority of articles in the field of health sciences in the country. It was followed by the Ministry of Health and Child Care with a percentage contribution of 19%, and the Biomedical Research and Training Institute with 14%. When only the output from the University of Zimbabwe was analysed, it was found that the university accounted for 90% of all health articles within the Zimbabwean university sector, and 81% of its articles were produced through international co-authorship. Although the percentage contribution of the three organisations in the Zimbabwean NGO sector (i.e. the Biomedical Research and Training Institute; Zvitambo, and the Centre for Sexual Health and HIV/AIDS Research Zimbabwe) was less than 20% of the country's article output, it is observed that the three organisations produced their articles almost exclusively through international co-authorship (96%–100%). From an analysis of the percentage contribution of international co-authorship, it can be concluded that between 2009 and 2016, international partners contributed significantly to the country's health research.

7.3 Article output in the natural sciences by the different national sectors

The article output of the national sectors in the natural sciences, by socio-political period, is presented in Table 7.8. For each sector in any period, the following four indicators of research production are reported:

- The total number of articles produced by the sector;
- The number of unique (non-duplicate) Zimbabwean organisations responsible for the article output in the sector;
- The average number of articles per Zimbabwean organisation in the sector; and

- The sector’s contribution (percentage share) to the total article output in the relevant period.

Table 7.8 shows that the average number of articles per year, as produced by the different Zimbabwean sectors in the natural sciences, increased over time: from an average of 44 articles per year in the first period to an average of 154 articles per year in the last period. This increase is largely attributed to more organisations in different sectors emerging to produce articles. Although their contributions were relatively low, some sectors in the category of ‘other national sectors’ nevertheless emerged to produce articles, in the last period especially. For example, in the first period, nine organisations in the business sector contributed to the article output whereas 19 contributed to the article output in the last period. Likewise, three local NGOs contributed to the article production in the first period, whereas in the last period, the number of local NGOs increased to 26.

Table 7.8 also shows that in the first period, out of a total of 487 articles, the majority (58%) were accounted for by the university sector. The government sector followed with a share of 38%. In the third period, 1 117 articles were produced. Of these, 66% were accounted for by the university sector. The government sector produced 22% of the total output in that period, and the INO sector had noticeable contributions of 11%.

The two most productive sectors in the last period were the university sector (72%) and the government sector (17%). These two sectors show different article output trends over time. For example, while the article output by the university sector increased from 54% in the first period to 72% in the last period, the contribution by the government sector decreased from 38% in the first period to 17% in the last period.

Table 7.8: Summary profile of article output in natural sciences, by national sector and socio-political period

National sectors	**1980–1990 (n=487)** [11 years; 44 articles per year]				**1991–1997 (n=610)** [7 years; 87 articles per year]				**1998–2008 (n=1117)** [11 years; 102 articles per year]				**2009–2016 (n=1232)** [8 years; 154 articles per year]			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	262	1	262	54%	380	2	190	62%	736	7	105	66%	884	9	98	72%
Government sector	186	17	11	38%	174	16	10	29%	242	20	12	22%	215	22	10	17%
INO sector	25	11	2	5%	42	19	2	7%	126	26	5	11%	178	32	7	14%
International research organisations	9	2	5	2%	21	5	4	3%	73	9	8	7%	105	8	13	9%
International NGOs	6	4	2	1%	7	6	1	1%	33	12	3	3%	50	17	3	4%
Inter-governmental organisations	4	2	2	1%	11	5	2	2%	20	4	5	2%	28	6	5	2%
International industry/businesses	6	3	2	1%	3	3	1	<1%	1	1	1	<1%	1	1	1	<1%
NGO sector	8	3	3	2%	4	2	2	1%	45	15	3	4%	100	26	4	8%
Other national sectors	9	10	1	2%	16	12	1	3%	51	24	2	5%	73	29	3	6%
Private hospitals and clinics	--	--	--	--	--	--	--	--	2	1	2	<1%	16	3	5	1%
Private schools and tertiary institutions	1	1	1	<1%	4	2	2	1%	5	3	2	0%	10	3	3	1%
Mission or faith-based hospitals	--	--	--	--	1	1	1	<1%	1	1	1	0%	1	3	1	<1%
Unions and associations	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	<1%
Industry/businesses	8	9	1	2%	11	9	1	2%	44	19	2	4%	45	19	2	4%

Note: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the 'unspecified' sector have been excluded.

Table 7.9 shows the results of a comparative analysis of the coverage of natural sciences articles in two article datasets. The first dataset was based on WoS and Scopus data, while the second was based on WoS, Scopus and NRDZ data. The objective was to determine how the addition of NRDZ data changes the summary profile for the natural sciences compared to when only Scopus and WoS data are used. From the comparison, it is observed that most Zimbabwean articles (905 out of 1 033) were indexed in Scopus and WoS, with the NRDZ accounting for only 128 (12%) additional articles. When comparing the indicators derived from Scopus and WoS data with the indicators based on all three data sources, a small but noticeable change of 12% was found

Table 7.9: Comparative profile of article output in natural sciences, by national sector in the period 2012–2016

National sectors	***Based on Scopus and WoS (n=905)*** *[5 years; 181 articles per year]*				***Based on Scopus, WoS and NRDZ (n=1033)*** *[5 years; 207 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	651	9	72	72%	778	9	86	75%
Government sector	165	20	8	18%	171	21	8	17%
INO sector	128	25	5	14%	130	25	5	13%
International research organisations	77	7	11	9%	79	7	11	8%
International NGOs	35	13	3	4%	35	13	3	3%
Inter-governmental organisations	18	4	5	2%	18	4	5	2%
International industry/businesses	1	1	1	<1%	1	1	1	<1%
NGO sector	85	22	4	9%	88	23	4	9%
Other national sectors	56	23	2	6%	56	23	2	5%
Industry/businesses	33	13	3	4%	33	13	3	3%
Private hospitals and clinics	15	3	5	2%	15	3	5	1%
Private schools and tertiary institutions	6	3	2	1%	6	3	2	1%
Mission or faith-based hospitals	1	3	1	<1%	1	3	1	<1%
Unions and associations	--	1	1	<1%	1	1	1	<1%

7.3.1 Co-authorship patterns of the most productive national sectors in the natural sciences

Presented in this section are the co-authorship patterns of the two most productive sectors in the last period; namely, the university and government sectors. The underlying analysis involved a series of cross-tabulations between two variables. As described in Section 7.2.2 above, since any article could involve simultaneous co-authorship by any of the productive sectors, the first variable therefore classified the two sectors into the following three mutually exclusive categories:

1. University sector only
2. Government sector only
3. Both sectors.

The second variable comprised all co-authoring entities (other than the two most productive national sectors), and classified those different entities into the following four mutually exclusive categories:

1. Other national sectors
2. International sector
3. Both other national sectors and international sector
4. Neither other national sectors nor international sector.

As stated before, ‘international sector’ refers to an international (non-Zimbabwean) author address. Table 7.10 shows the results of the series of cross-tabulations between the two variables that were created, revealing the concentrations of co-authorship in each of the four socio-political periods. For each period, the cross-tabulation between the two variables produced a set of 12 percentages which summed to 100%. All percentage shares of at least 10% were taken to imply a concentration of co-authorship.

According to Table 7.10, in the first period, the university and government sectors were responsible for 443 articles. Of these, 43% were produced by the university sector on its own, without any co-authorship by other national sectors or the international sector. The government sector produced 30% of the total articles, also on its own, without any co-authorship by other national sectors or the international sector. Both the university and government sectors each respectively produced 14% and 10% of the total article output in collaboration with international authors. This collaboration pattern was more or less replicated in the second period. In the third period, the two sectors produced a total of 919 articles. Of these, 42% were produced by the university sector in collaboration with international authors. The government sector produced 11% of the total article output in collaboration with international authors, and only 6% on its own, without any co-authorship by other national sectors or the international sector. It can thus be concluded that the co-authorship patterns and trends of the two productive sectors in the natural sciences changed over time. In the first period, each sector produced a larger share of its output on its own, without any co-authorship by other national sectors or international sector. In the last period, the output by the university sector dominated that of the government sector, to the extent that the government's share was minimal compared to that of the university sector.

Table 7.10: Co-authorship patterns of the two most productive national sectors in natural sciences, by socio-political period

Mutually exclusive classification 1: two most productive national sectors	1980–1990 (n=443)				1991–1997 (n=537)				1998–2008 (n=919)				2009–2016 (n=1002)			
	Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector			
	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector
University sector only	1%	14%	<1%	43%	1%	26%	0%	41%	3%	42%	1%	27%	5%	45%	3%	25%
Government sector only	<1%	10%	<1%	30%	0%	11%	<1%	17%	2%	11%	1%	6%	3%	8%	<1%	1%
Both sectors	0%	0%	<1%	1%	0%	1%	<1%	1%	<1%	3%	<1%	3%	2%	3%	<1%	4%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following three categories from Table 7.8: ‘INO sector’, ‘NGO sector’ and ‘other national sectors’.

7.3.2 Article output of the most productive Zimbabwean organisations in natural sciences

This section presents the article output of the organisations in the two most productive sectors; namely, the university and government sectors in the field of the natural sciences. Presented first are organisations in the university sector, followed by organisations in the government sector. Lastly, the six most productive Zimbabwean organisations in natural sciences, across sectors, are identified and highlighted.

- ***University sector***

According to Table 7.11, in the first period, only one university – the University of Zimbabwe – was responsible for 262 articles in the natural sciences. In the second period, two universities – the University of Zimbabwe, and the National University of Science and Technology – produced 380 articles. Of this total, 94% of the articles were produced by the University of Zimbabwe and only 6% were accounted for by the National University of Science and Technology. The relative percentage share of articles produced by the University of Zimbabwe decreased from 100% in the first period to 63% in the last period. This decrease is attributable to more universities emerging to contribute articles in the natural sciences. For example, the 884 articles produced in the last period were accounted for by nine universities, as compared to the first period where all articles were produced by one university.

Table 7.11: Article output in natural sciences, by university and socio-political period

Zimbabwean universities	1980-1990 (n=262)		1991-1997 (n= 380)		1998-2008 (n=736)		2009-2016 (n=884)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	262	100%	359	94%	605	82%	554	63%
National University of Science and Technology	--	--	24	6%	110	15%	138	16%
Chinhoyi University of Technology	--	--	--	--	8	1%	88	10%
Bindura University of Science Education	--	--	--	--	34	5%	83	9%
Midlands State University	--	--	--	--	10	1%	64	7%
Great Zimbabwe University	--	--	--	--	--	--	17	2%
Harare Institute of Technology	--	--	--	--	1	<1%	15	2%
Zimbabwe Open University	--	--	--	--	2	<1%	12	1%
Lupane State University	--	--	--	--	--	--	10	1%

Figure 7.4 provides an analysis of the collaboration trends and patterns of the University of Zimbabwe. The figure shows that there was a decrease in the percentage share of articles produced through single authorship, and a consistent increase in the share of articles produced through both international and national collaboration. For example, articles produced through both international and national collaboration grew from 4% in the first period to 33% in the last period, while those produced through single authorship dropped from 45% in the first period to 6% in the last period. The percentage share of articles produced through national collaboration only increased from 31% in the first period to a peak of 41% in the second period, and maintained a constant of 26% and 29% in the third and fourth periods, respectively.

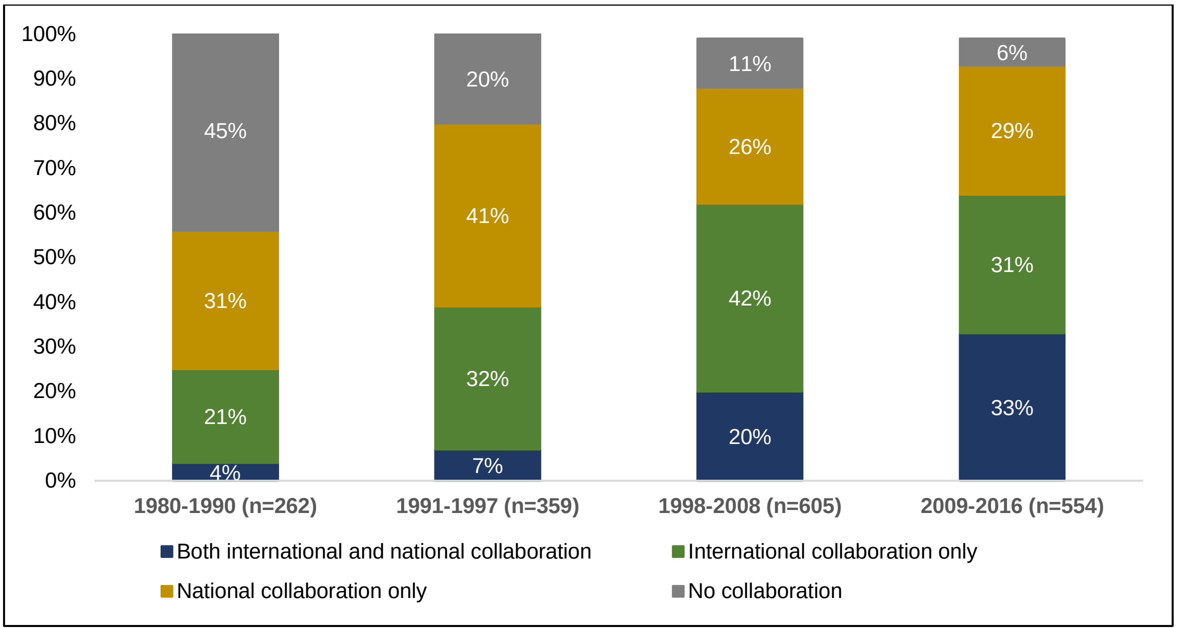

Figure 7.4: National versus international collaboration of the University of Zimbabwe in natural sciences, by socio-political period

The collaboration trends of the National University of Science and Technology in natural sciences are presented in Figure 7.5. The university was established in 1991 which means that publication data are available only from the second period onwards. It can be seen in the figure that the share of articles produced through single authorship decreased from 54% in the second period to 6% in the last period. The share of articles produced through national collaboration only decreased from 38% in the second period to 31% in the third period, but increased again to 38% in the last period. When only the last period is considered, it can be observed that the majority (71%) of natural sciences articles were produced through national collaboration. Of this total, 33% involved both national and international collaboration.

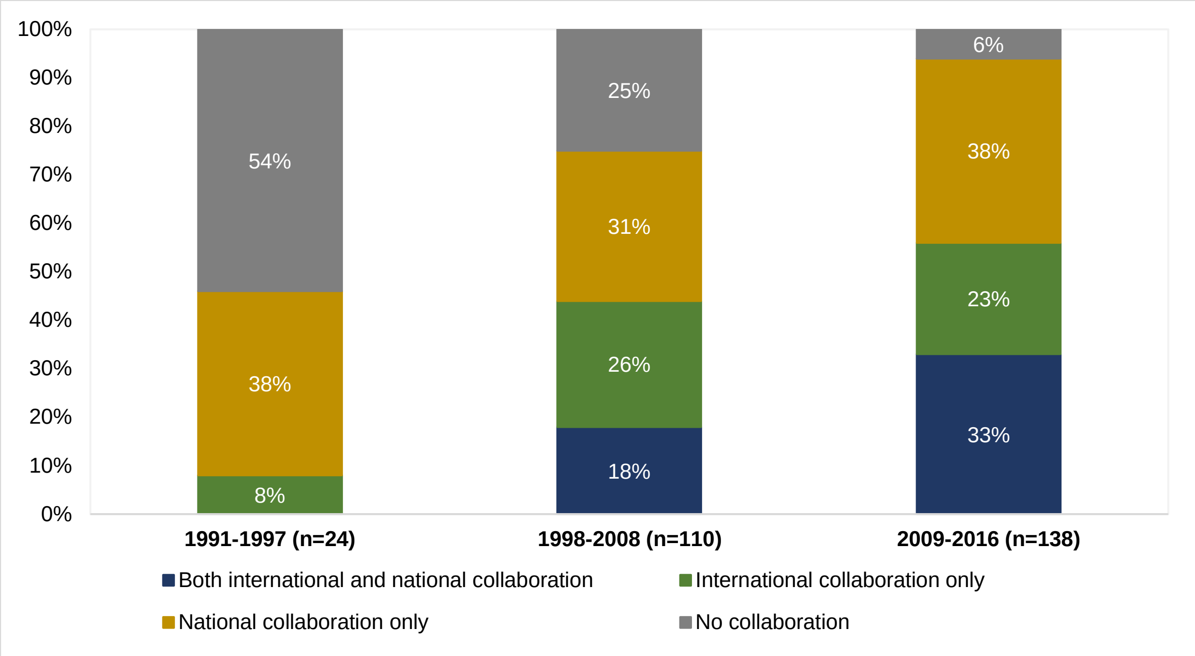

Figure 7.5: National versus international collaboration of the National University of Science and Technology in natural sciences, by socio-political period

- ***Government sector***

The natural sciences article output from organisations in the government sector is shown in Table 7.12 below. The Ministry of Lands, Agriculture and Rural Settlement was found to be the largest producer of natural sciences articles in the first (51%), second (49%) and third (38%) periods. The Zimbabwe Parks and Wildlife Management Authority emerged to be the largest producer of natural sciences articles in the last period with a percentage contribution of 34%. This is followed by the Ministry of Health and Child Care with a percentage contribution of 30%. The percentage contribution of articles by the Ministry of Health and Child Care increased from 6% in the first period to 30% in the last period. Within the ministry are several organisations producing natural sciences research as shown in Appendix 9. As can be seen in the appendix, the Ministry of Health and Child Care as a distinct department accounted for 63% of the natural sciences articles in the last period. The National Institute of Health Research had a dominant contribution in the first period (55%), second period (75%), and the third period (54%). Its contribution dropped quite significantly to 14% in the last period.

The list of organisations contributing to natural sciences research articles within the Ministry and Lands, Agriculture and Rural Settlement is shown in Appendix 10. As can been seen in the appendix, the most productive organisation within this ministry was the Department of Research and Specialist Services (DRSS).

Table 7.12: Article output in natural sciences, by government organisation and socio-political period

Zimbabwean organisations in government sector	1980-1990 (n=186)		1991-1997 (n= 174)		1998-2008 (n=242)		2009-2016 (n=215)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Zimbabwe Parks and Wildlife Management Authority	46	25%	21	12%	43	18%	73	34%
Ministry of Health and Child Care	11	6%	12	7%	26	11%	65	30%
Ministry of Lands, Agriculture and Rural Settlement	94	51%	86	49%	93	38%	27	13%
Natural History Museum of Zimbabwe	14	8%	20	11%	27	11%	16	7%
Harare City Council	--	--	1	1%	3	1%	7	3%
Scientific and Industrial Research and Development Centre (SIRDC)	--	--	3	2%	3	1%	5	2%
Upper Manyame Subcatchment Council	--	--	--	--	--	--	5	2%
Meteorological Services Department of Zimbabwe	4	2%	9	5%	16	7%	4	2%
National Museums and Monuments of Zimbabwe (NMMZ)	--	--	--	--	--	--	3	1%
Chisungu Primary School	--	--	--	--	--	--	2	1%
Morgenster Teachers College	--	--	--	--	--	--	2	1%
Zimbabwe National Water Authority	--	--	--	--	6	2%	2	1%
Ministry of Environment, Water and Climate	1	1%	2	1%	1	<1%	2	1%
Zimbabwe National Statistics Agency (ZIMSTAT)	--	--	--	--	--	--	1	<1%
National Art Gallery	--	--	--	--	--	--	1	<1%
National Gallery of Zimbabwe	--	--	--	--	--	--	1	<1%
Kushinga Phikelela Polytechnic	--	--	--	--	--	--	1	<1%
Research Council of Zimbabwe	--	--	--	--	--	--	1	<1%
Gonarezhou Conservation Project	--	--	--	--	--	--	1	<1%
Mzingwane Catchment Council	--	--	--	--	--	--	1	<1%
Bulawayo City Council	--	--	--	--	2	1%	1	<1%
Harare Polytechnic College	1	1%	1	1%	--	--	1	<1%
Ministry of Mines and Mining Development	3	2%	6	3%	6	2%	--	--
Zimbabwe Electricity Supply Authority	--	--	--	--	5	2%	--	--
Forestry Commission of Zimbabwe - Forest Research Centre	1	1%	5	3%	4	2%	--	--
Guruve Rural District Council	--	--	--	--	3	1%	--	--
Mana Pools National Park	5	3%	4	2%	--	--	--	--
Ministry of Transport and Infrastructural Development	1	1%	--	--	2	1%	--	--
Ministry of Local Government, Public Works and National Housing	--	--	--	--	2	1%	--	--
Mutare City Council	--	--	--	--	1	<1%	--	--
Ministry of Rural Development, Promotion	--	--	--	--	1	<1%	--	--

Zimbabwean organisations in government sector	1980-1990 (n=186)		1991-1997 (n= 174)		1998-2008 (n=242)		2009-2016 (n=215)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
and Preservation of National Culture and Heritage								
Pafiwa Secondary School	--	--	--	--	1	<1%	--	--
Gweru Polytechnical College	--	--	--	--	1	<1%	--	--
Ministry of Primary and Secondary Education	1	1%	2	1%	--	--	--	--
Shabanie Mine Zvishavane	--	--	1	1%	--	--	--	--
Zimbabwe Museum of Human Sciences	--	--	1	1%	--	--	--	--
Department of Natural Resources	--	--	1	1%	--	--	--	--
Posts and Telecommunications Corporation of Zimbabwe	1	1%	--	--	--	--	--	--
Zimbabwe Defence Forces	1	1%	--	--	--	--	--	--
Zimbabwe Institute of Development Studies (ZIDS)	1	1%	--	--	--	--	--	--
Department of Natural Resources	1	1%	--	--	--	--	--	--
Ministry of Energy and Power Development	1	1%	--	--	--	--	--	--

Figure 7.6 shows an analysis of the collaboration trends and patterns of the Ministry of Lands, Agriculture and Rural Settlement. The figure shows that the percentage share of articles produced through single authorship systematically decreased throughout the study period, while that of articles produced through both international and national collaboration increased. For example, articles produced through both international and national collaboration increased from 2% in the first period to 30% in the last period. Articles produced through single authorship dropped from 40% in the first period to 7% in the last period.

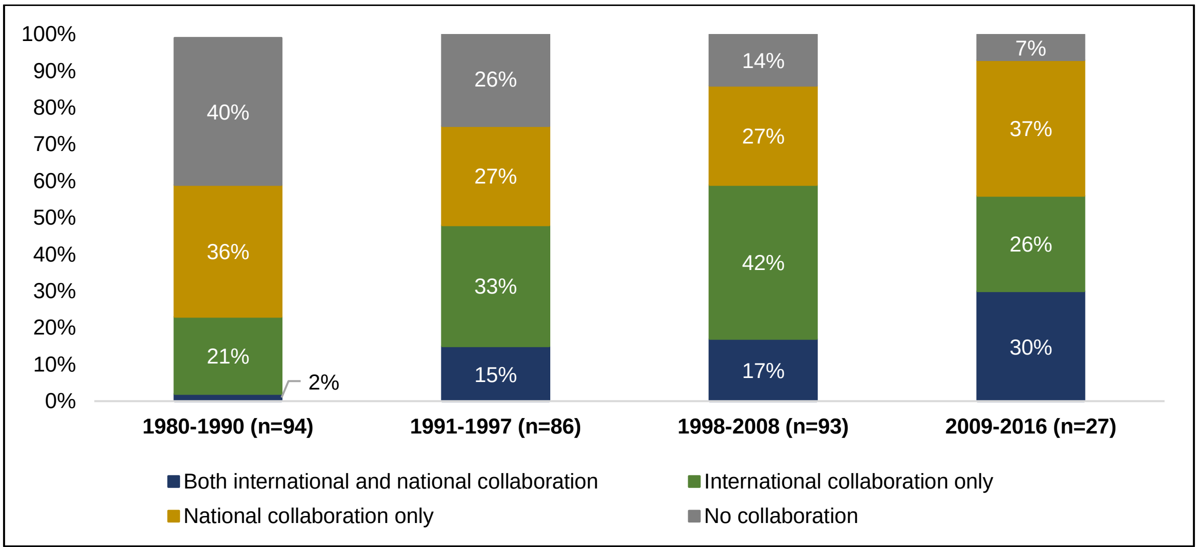

Figure 7.6: National versus international collaboration of the Ministry of Lands, Agriculture and Rural Settlement in natural sciences, by socio-political period

Figure 7.7 shows the collaboration trends and patterns of the Zimbabwe Parks and Wildlife Management Authority. As can be seen in the figure, the percentage share of articles produced through single authorship dropped from 54% in the first period to 3% in the last period. The share of articles produced through international collaboration only grew from 20% in the first period to 47% in the third period, and slightly dropped to 40% in the last period.

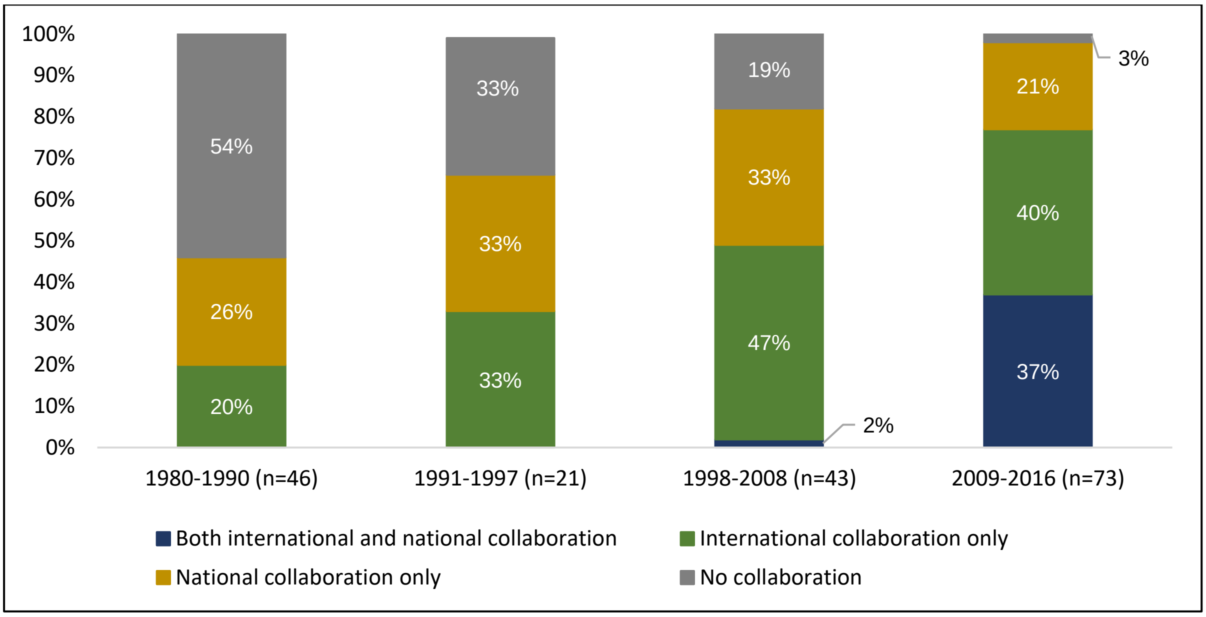

Figure 7.7: National versus international collaboration of the Zimbabwe Parks and Wildlife Management Authority in natural sciences, by socio-political period

- ***The six most research-productive organisations in the natural sciences***

Finally, based on Tables 7.11 and 7.12, the six most productive Zimbabwean organisations in the last period, across the two sectors, could be identified. The six organisations are presented in Table 7.13.

Table 7.13: Summary profile of the six most research-productive organisations in natural sciences, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	554	55%	63%	64%
National University of Science and Technology (University sector)	138	14%	16%	57%
Chinhoyi University of Technology (University sector)	88	9%	10%	31%
Zimbabwe Parks and Wildlife Management Authority (Government sector)	73	7%	34%	77%
Ministry of Health and Child Care (Government sector)	65	6%	30%	82%
Ministry of Lands, Agriculture and Rural Settlement (Government sector)	27	3%	13%	56%

Table 7.13 shows that between 2009 and 2016, the University of Zimbabwe, with a percentage contribution of 55%, produced the majority of articles in the field of the natural sciences in the country. It was followed by the National University of Science and Technology with a percentage contribution of 14%, and the Chinhoyi University of Technology with 9%. When only the output from the University of Zimbabwe was analysed, it was found that the university accounted for 63% of all natural sciences articles within the Zimbabwean university sector, and 63%% of its articles were produced through international co-authorship. When only the Ministry of Health and Child Care was analysed, it was found that the ministry accounted for 6% of all natural sciences articles in the country, and 30% of all natural sciences articles within the government sector. Furthermore, 82% of its articles were produced through international co-authorship.

7.4 Article output in the agricultural sciences by the different national sectors

The focus in this section shifts to the field of agricultural sciences. Table 7.14 shows the article output of the national sectors in the agricultural sciences, by socio-political period. In terms of the four indicators of research production (see Section 7.2), it is seen that the average number of articles per year, as produced by the different Zimbabwean sectors in the agricultural sciences, increased from an average of 28 articles per year in the first period, to an average of 70 articles per year in the last period. The increase in the article output per year in the last period can be explained by more Zimbabwean organisations (e.g. universities, government organisations and local NGOs) emerging to produce research. For instance, in the first period only one university contributed to the article output whereas 10 universities contributed to the article output in the last period. Likewise, nine INOs participated in Zimbabwe's article production in the first period compared to 14 in the last period.

Table 7.14 shows that in the first period, out of a total of 309 articles, the majority (54%) were produced by the government sector. This is followed by the university sector with a percentage contribution of 38%. Although the government sector contributed the majority of articles in the first period, its percentage contribution decreased significantly from 54% in the first period to 17% in the last period.

When only the last period was considered, it was found that the three most productive sectors were the university sector (63%), followed by INOs (36%) and the government sector (17%). The INO sector showed a systematic increase in article output over time, starting with only 8% in the first period, to a high percentage contribution of 36% in the last period. The most prolific organisations within the INO sector were international research organisations operating in the country. These organisations more than doubled their percentage contribution: from 5% in the first period to 34% in the last.

Table 7.14: Summary profile of article output in agricultural research, by national sector and socio-political period

National sectors	1980–1990 (n=309) [11 years; 28 articles per year]				1991–1997 (n=450) [7 years; 64 articles per year]				1998–2008 (n=772) [11 years; 70 articles per year]				2009–2016 (n=560) [8 years; 70 articles per year]			
	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period
University sector	117	1	117	38%	238	2	119	53%	459	6	77	59%	354	10	35	63%
INO sector	24	9	3	8%	54	17	3	12%	177	24	7	23%	202	14	14	36%
International research organisations	15	5	3	5%	33	6	6	7%	144	7	21	19%	190	5	38	34%
International NGOs	5	2	3	2%	12	4	3	3%	15	10	2	2%	6	5	1	1%
Inter-governmental organisations	3	1	3	1%	6	4	2	1%	8	3	3	1%	5	3	2	1%
International industry/businesses	1	1	1	<1%	3	3	1	1%	10	4	3	1%	5	1	5	1%
Government sector	168	6	28	54%	174	7	25	39%	192	9	21	25%	94	8	12	17%
NGO sector	--	--	--	--	5	3	2	1%	16	10	2	2%	10	7	1	2%
Other national sectors	12	7	3	4%	12	10	1	3%	15	9	2	2%	28	14	2	5%
Private schools and tertiary institutions	--	--	--	--	1	1	1	0%	4	1	4	1%	15	3	5	3%
Industry/businesses	11	6	3	4%	10	8	1	2%	9	7	1	1%	12	10	1	2%
Unions and associations	1	1	1	<1%	1	1	1	<1%	2	1	2	<1%	1	1	1	<1%
Private hospitals and clinics	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the 'unspecified' sector have been excluded.

What follows is a comparative analysis of agricultural sciences articles (Table 7.15) based, on the one hand, on Scopus and WoS data and, on the other, on Scopus, WoS and NRDZ data. The main aim of this comparative analysis was to determine how the addition of NRDZ data changes the summary profile for the agricultural sciences compared to when only Scopus and WoS data are used. From the comparison, it is observed that almost the entire article output of Zimbabwe in the agricultural sciences (398 out of 401) were indexed in Scopus and WoS, with the NRDZ accounting for only three additional articles. This means that the value of the indicators do not change because the NRDZ contributed almost nothing to what was already indexed in Scopus and WoS.

Table 7.15: Comparative profile of article output in agricultural research, by national sector in the period 2012–2016

National sectors	Based on Scopus and WoS (n=398) *[5 years; 80 articles per year]*				Based on Scopus, WoS and NRDZ (n=401) *[5 years; 80 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	263	10	26	66%	266	10	27	66%
INO sector	148	10	15	37%	149	11	15	37%
International research organisations	142	5	28	36%	143	6	28	36%
International NGOs	3	3	1	1%	3	3	1	1%
Inter-governmental organisations	1	1	1	<1%	1	1	1	<1%
International industry/businesses	4	1	4	1%	4	1	4	1%
Government sector	58	8	7	15%	59	8	7	15%
NGO sector	6	3	2	2%	6	3	2	1%
Other national sectors	21	11	2	5%	21	11	2	5%
Industry/businesses	9	8	1	2%	9	8	1	2%
Private schools and tertiary institutions	12	3	4	3%	12	3	4	3%
Unions and associations	--	--	--	--	--	--	--	--
Private hospitals and clinics	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--

7.4.1 Co-authorship patterns of the most productive national sectors in the agricultural sciences

The focus of this section is on the co-authorship patterns of the three most productive national sectors in agricultural sciences; namely, the university sector, international research organisations, and the government sector. Table 7.16 below shows that between 1980 and 1990, the three sectors together produced a total of 290 agricultural sciences articles. Of these, 40% were produced by the government sector on its own without any co-authorship with other Zimbabwean sectors or international authors. On the other hand, the university sector accounted for 28% of the total article output, also on its own without any co-authorship by other Zimbabwean sectors or international authors. In the last period, a total of 533 articles were produced. Of these, 29% were produced by the university sector in collaboration with international authors. The international research organisations operating in the country were responsible for 21% of the total articles in collaboration with international authors. Together, the two sectors (university and international research organisations operating in the country), each producing research in collaboration with international authors, were responsible for 50% of the 533 articles produced in the last period. These results indicate that in the last period, international co-authors played a significant role in the production of agricultural articles in the country.

Table 7.16: Co-authorship patterns of the three most productive national sectors in agricultural research, by socio-political period

Mutually exclusive classification 1: three most productive national sectors	1980–1990 (n=290)				1991–1997 (n=415)				1998–2008 (n=722)				2009–2016 (n=533)			
	Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector			
	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector
University sector only	0%	9%	1%	28%	0%	16%	1%	33%	1%	32%	2%	20%	3%	29%	1%	17%
Government sector only	0%	14%	0%	40%	1%	15%	<1%	19%	<1%	13%	1%	4%	0%	6%	1%	<1%
International research organisation sector only	0%	3%	0%	2%	0%	4%	0%	3%	<1%	16%	0%	1%	<1%	21%	<1%	3%
Both university sector and government sector	1%	<1%	0%	2%	0%	3%	<1%	3%	0%	4%	0%	3%	1%	2%	<1%	4%
Both university sector and international research organisation sector	0%	0%	0%	<1%	0%	<1%	0%	<1%	0%	1%	0%	1%	<1%	5%	<1%	3%
Both government sector and international research organisation sector	0%	0%	0%	<1%	0%	<1%	0%	0%	0%	1%	0%	0%	0%	1%	0%	<1%
All three sectors	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	1%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following categories from Table 7.14: ‘NGO sector’, ‘other national sectors’ and the remaining three subcategories of the ‘INO sector’.

7.4.2 Article output of the most productive Zimbabwean organisations in the agricultural sciences

The focus now shifts to the article output of organisations in each of the three productive sectors (i.e. university sector, government sector, and the international research organisation sector). Organisations in the university sector are presented first, followed by the international research organisation sector. Organisations in the government sector follow. Lastly, a summary profile of the top-producing individual organisations in agricultural sciences is provided.

- ***University sector***

The results in Table 7.17 show that the University of Zimbabwe was responsible for 100% of all agricultural articles in the first and second periods. In the third period, six universities were responsible for a total of 459 articles. Of these articles, the largest share (88%) were produced by the University of Zimbabwe. The Bindura University of Science Education followed with a small share of 5%. The table shows that in the last period, ten universities produced a total of 354 articles. The University of Zimbabwe still maintained its dominant status and was responsible for 68% of the total articles. It was followed by Bindura University of Science Education (14%), and the Chinhoyi University of Technology (12%).

Table 7.17: Article output in agricultural sciences, by university and socio-political period

Zimbabwean universities	1980-1990 (n=117)		1991-1997 (n= 238)		1998-2008 (n=459)		2009-2016 (n=354)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	117	100%	237	100%	404	88%	242	68%
Bindura University of Science Education	--	--	--	--	23	5%	49	14%
Chinhoyi University of Technology	--	--	--	--	7	2%	41	12%
National University of Science and Technology	--	--	1	<1%	24	5%	28	8%
Midlands State University	--	--	--	--	19	4%	25	7%
Zimbabwe Open University	--	--	--	--	7	2%	7	2%
Lupane State University	--	--	--	--	--	--	7	2%
Marondera College of Agricultural Science and Technology	--	--	--	--	--	--	4	1%
Great Zimbabwe University	--	--	--	--	--	--	4	1%
Harare Institute of Technology	--	--	--	--	--	--	1	<1%

The collaboration trends and patterns of the University of Zimbabwe in agricultural sciences are provided in Figure 7.8. It can be seen in the figure that there was a significant decrease in the number of articles produced through single authorship, and systematic growth in the number of articles produced through both international and national collaboration. For instance, articles produced through single authorship dropped from 41% in the first period to 0% in the last period. Articles produced through both international and national collaboration increased significantly from 6% in the first period to 36% in the last period. Articles produced through national collaboration only fluctuated throughout the period under review. For example, the share of articles produced through national collaboration increased from 37% in the first period to 49% in the second period, dropped to 32% in the third period, and rose again to 44% in the last period.

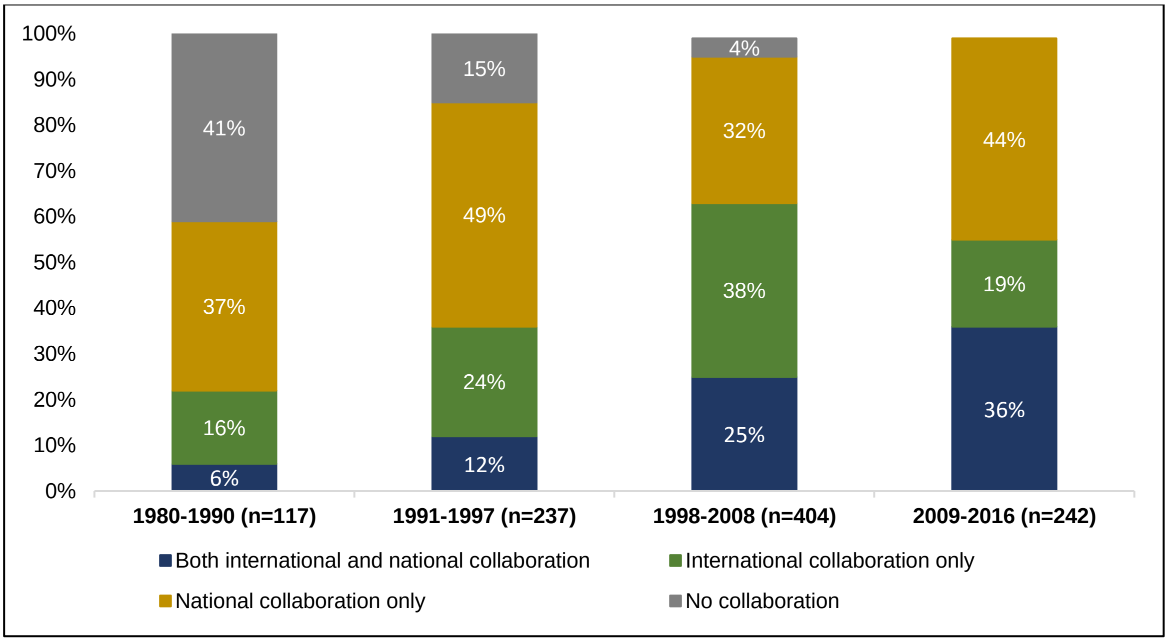

Figure 7.8: National versus international collaboration of the University of Zimbabwe in agricultural sciences, by socio-political period

Figure 7.9 shows the collaboration trends of researchers at Bindura University of Science Education. The contribution by the Bindura University of Science Education is only seen in the third period because the university was only established in 2000. In the first decade of its establishment, the university produced 23 agricultural sciences articles. The majority of its articles in that period (74%) were produced through national collaboration only. Between 2009 and 2016, the university produced a total of 49 articles. These articles were produced fairly equally through national collaboration only (33%), international collaboration only (31%), and both international and national collaboration (35%).

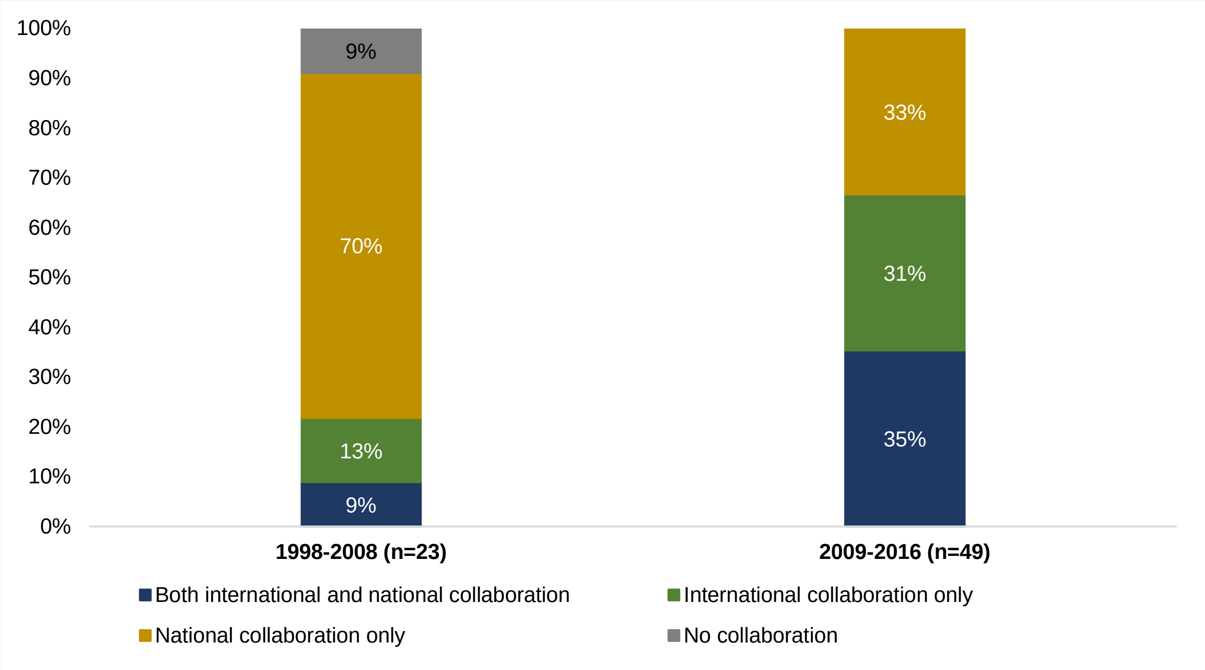

Figure 7.9: National versus international collaboration of Bindura University in agricultural sciences, by socio-political period

- ***International research organisations in the INO sector***

Agricultural sciences is the only field with a significant article contribution by the international research organisation sector. Table 7.18 below provides a list of all organisations in the sector responsible for agricultural sciences articles in the country. It is observed in the table that the International Maize and Wheat Improvement Center (CIMMYT) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) had a significant and consistent presence in the period under review. The University of Florida/USAID/SADC Heartwater Research Project also made a significant contribution in the first three periods. One explanation for its lack of presence in the last period could be that the research partnership came to an end in the third period.

Table 7.18: Article output in agricultural sciences, by international research organisation and socio-political period

Zimbabwean international research organisations	1980-1990 (n=15)		1991-1997 (n=33)		1998-2008 (n=144)		2009-2016 (n=190)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
International Maize and Wheat Improvement Center (CIMMYT)	3	20%	7	21%	44	31%	112	59%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	7	47%	10	30%	39	27%	53	28%
International Centre for Tropical Agriculture (CIAT)	--	--	--	--	10	7%	26	14%
Cirad – Zimbabwe	--	--			2	1%	10	5%
WaterNet – Zimbabwe	--	--	--	--	--	--	1	1%
World Agroforestry Centre	--	--	2	6%	22	15%	--	--
University of Florida/USAID/SADC Heartwater Research Project	3	20%	11	33%	14	10%	--	--
Center for International Forestry Research (CIFOR)	1	7%	2	6%	13	9%	--	--
French Embassy in Harare	1	7%	--	--	--	--	--	--

As shown in Table 7.18, the most prolific organisations in the international research organisation sector were CIMMYT and ICRISAT. The collaboration patterns of these organisations are provided in Figure 7.10. It can be seen in the figure that the two organisations had the same collaboration patterns. Between 1998 and 2008, they produced the majority of their articles through international collaboration only. However, between 2009 and 2016, the majority of articles produced by the organisations involved both international and national collaboration only. For example, during the third period, ICRISAT produced 82% of its articles through international collaboration only. In the last period, the organisation produced 45% of its articles through both international and national collaboration, and 28% of its articles through international collaboration only.

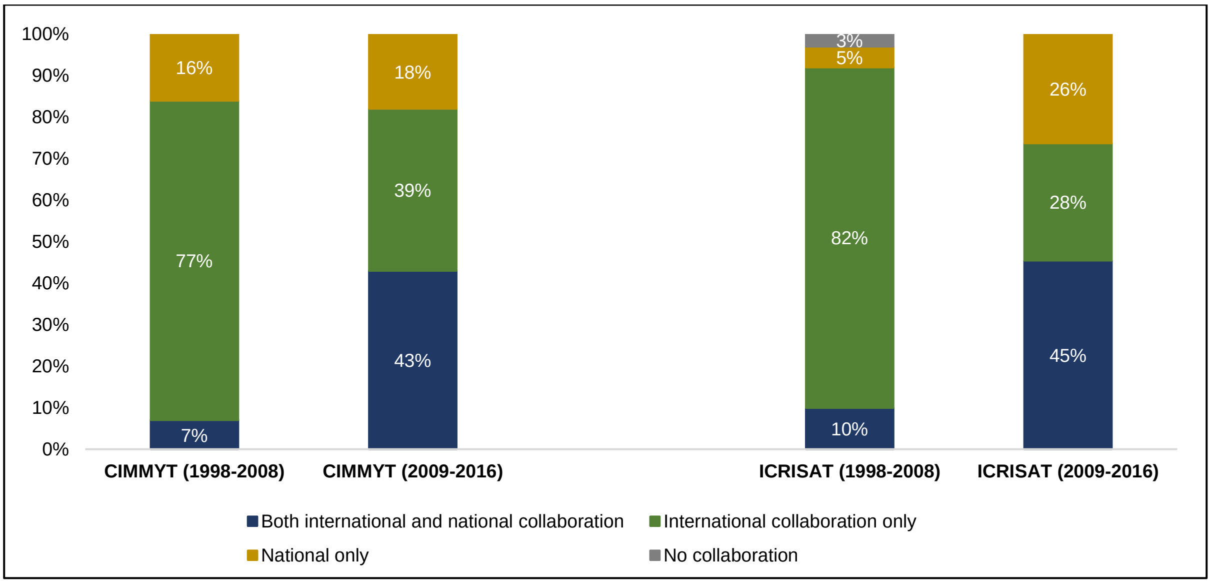

Figure 7.10: National versus international collaboration of CIMMYT and ICRISAT, in agricultural sciences, by socio-political period

- ***Government sector***

An analysis of the article contribution of organisations in the government sector (Table 7.19) was undertaken. As can be seen in the table, the Ministry of Lands, Agriculture and Rural Settlement was the largest contributor of all agricultural research articles in the country. The percentage contribution by the ministry fluctuated throughout the study period. For example, its percentage share of articles dropped from 88% in the first period to 76% in the second period, and rose to 86% in the third period, slightly dropping to 82% in the last period. Within the ministry are several organisations which produce agricultural sciences articles. A list of the organisations in the ministry is provided in Appendix 11. The appendix shows that the Department of Research and Specialist Services (DRSS), with percentage contributions of 49%, 52%, 45% and 71%, respectively, in the adjacent periods, is the largest producer of agricultural sciences articles. It is followed by the Livestock and Veterinary department with contributions of 31%, 37%, 39% and 19%.

Table 7.19: Article output in agricultural sciences, by government organisation and socio-political period

Zimbabwean organisations in government sector	1980-1990 (n=168)		1991-1997 (n= 174)		1998-2008 (n=192)		2009-2016 (n=94)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Ministry of Lands, Agriculture and Rural Settlement	148	88%	133	76%	166	86%	77	82%
Forestry Commission of Zimbabwe - Forest Research Centre	10	6%	19	11%	15	8%	7	7%
Zimbabwe Parks and Wildlife Management Authority	5	3%	13	7%	--	--	4	4%
Ministry of Health and Child Care	3	2%	7	4%	4	2%	3	3%
Harare City Council	--	--	--	--	1	1%	1	1%
Zimbabwe National Water Authority	--	--	--	--	--	--	1	1%
Mzingwane Catchment Council	--	--	--	--	--	--	1	1%
Masvingo Polytechnic College	--	--	--	--	--	--	1	1%
Zimbabwe College of Forestry	--	--	--	--	5	3%	--	--
Meteorological Services Department of Zimbabwe	1	1%	--	--	1	1%	--	--
Pafiwa Secondary School	--	--	--	--	1	1%	--	--
Natural History Museum of Zimbabwe	--	--	--	--	1	1%	--	--
Bulawayo City Council	--	--	--	--	1	1%	--	--
Ministry of Mines and Mining Development	--	--	4	2%	--	--	--	--
Harare Polytechnic College	--	--	1	1%	--	--	--	--
Environmental Management Agency (EMA)	--	--	1	1%	--	--	--	--
Mana Pools National Park	1	1%	--	--	--	--	--	--

Figure 7.11 shows the collaboration trends and patterns of the Ministry of Lands, Agriculture and Rural Settlement. The figure shows that there was a consistent increase in the share of articles produced through both international and national collaboration, and a systematic decrease in the percentage share of articles produced through single authorship only. For example, the share of articles produced through single authorship decreased from 30% in the first period to 3% in the last period, while the share of articles produced through both international and national collaboration increased from 2% in the first period to 35% in the last period.

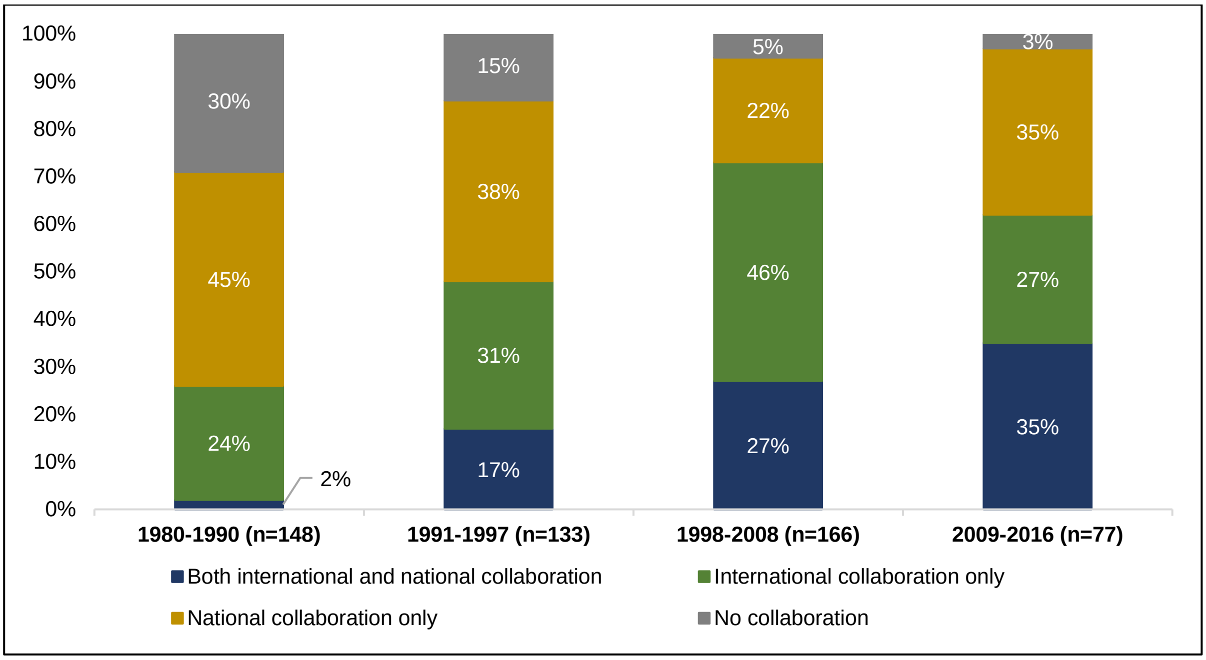

Figure 7.11: National versus international collaboration of the Ministry of Lands, Agriculture and Rural Settlement in agricultural sciences, by socio-political period

- ***The six most research-productive organisations in the agricultural sciences***

Lastly, this section provides a summary profile of the percentage contributions of the top-producing organisations in the agricultural sciences between 2009 and 2016. Based on Tables 7.17, 7.18 and 7.19, the six most productive Zimbabwean organisations in the last period, across all three productive sectors, were identified. These organisations are presented in Table 7.20.

Table 7.20: Summary profile of the six most research-productive organisations in agricultural sciences, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	242	43%	68%	56%
International Maize and Wheat Improvement Centre (CIMMYT) (INO sector)	112	20%	59%	82%
Ministry of Lands, Agriculture and Rural Settlement (Government sector)	77	14%	77%	62%
International Crops Research Institute for Semi-Arid Tropics (INO sector)	53	9%	28%	74%
Bindura University of Science Education (University sector)	49	9%	14%	65%
Chinhoyi University of Technology (University sector)	41	7%	12%	54%

Based on Table 7.20, it is observed that between 2009 and 2016, the majority of agricultural articles in the country (43%), were produced by the University of Zimbabwe. This was followed by an INO, the CIMMYT, with a percentage contribution of 20%, and the Ministry of Lands, Agriculture and Rural Settlement with 14%. When only the output from CIMMYT was analysed, it was found that the organisation accounted for 59% of all agricultural sciences articles within the INO sector, and 82% of its articles were produced through international co-authorship. The Ministry of Lands, Agriculture and Rural Settlement accounted for 77% of all agricultural articles within the government sector, and 62% of its articles were produced through international co-authorship. Based on an inspection of the percentage contribution of international co-authorship it can be concluded that between 2009 and 2016, international partners contributed significantly to the country's agricultural research.

7.5 Article output in the social sciences by the different national sectors

The article output of the national sectors in the social sciences, by socio-political period, is presented in Table 7.21. As was the case with other fields, the following four research production indicators are reported on:

- The total number of articles produced by the sector;
- The number of unique (non-duplicate) Zimbabwean organisations responsible for the article output in the sector;
- The average number of articles per Zimbabwean organisation in the sector; and
- The sector's contribution (percentage share) to the total article output in the relevant period.

It is shown in Table 7.21 that the average number of articles per year, as produced by the different Zimbabwean sectors in the social sciences, increased from an average of 21 articles per year in the first period to an average of 89 articles per year in the last period. The increase in the article output per year in the last period could be explained by more Zimbabwean organisations (e.g. universities, local NGOs and INOs) emerging to produce research in the field of the social sciences. For instance, in the first period, three local NGOs contributed to the article output whereas 30 local NGOs contributed to the article output in the last period. Similarly, seven INOs participated in Zimbabwe's research production in the first period whereas in the last period 23 participated.

Table 7.1 also shows that out of a total of 232 articles produced in the first period, the majority (75%) were produced by the university sector. This was followed by the government sector with a percentage contribution of 16%. In the third period, the same trend is observed. Out of a total of 281 articles, the majority (76%) were produced by the university sector, and 11% were accounted for by the government sector.

The three most productive sectors in the last period were, in order of productivity: the university sector (75%), the local NGO sector (11%), and the government sector (10%). The local NGO sector was found to be the only sector that showed a systematic increase in article output over time, from 2% in the first period to 11% in the last period. The INO sector also showed a steady increase over time, from 4% in the first period to 14% in the third period, where after it dropped to 8% in the last period.

Table 7.21: Summary profile of article output in social sciences, by national sector and socio-political period

National sectors	1980–1990 (n=232) [11 years; 21 articles per year]				1991–1997 (n=281) [7 articles; 40 articles per year]				1998–2008 (n=404) [11 years; 37 articles per year]				2009–2016 (n=711) [8 years; 89 articles per year]			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	173	1	173	75%	214	2	107	76%	272	7	39	67%	535	9	59	75%
Government sector	37	12	3	16%	31	12	3	11%	42	15	3	10%	73	35	2	10%
NGO sector	4	3	1	2%	13	13	1	5%	33	16	2	8%	75	30	3	11%
INO sector	9	7	1	4%	16	12	1	6%	58	30	2	14%	54	23	2	8%
International research organisations	--	--	--	--	1	1	1	<1%	16	6	3	4%	24	5	5	3%
Inter-governmental organisations	4	4	1	2%	2	1	2	1%	16	5	3	4%	19	8	2	3%
International NGOs	5	3	2	2%	12	9	1	4%	27	19	1	7%	13	10	1	2%
International industry/businesses	--	--	--	--	1	1	1	<1%	--	--	--	--	--	--	--	--
Other national sectors	3	3	1	1%	7	5	1	2%	18	11	2	4%	27	13	2	4%
Industry/businesses	3	3	1	1%	4	4	1	1%	8	6	1	2%	9	5	2	1%
Private schools and tertiary institutions	--	--	--	--	--	--	--	--	8	2	4	2%	15	5	3	2%
Mission or faith-based hospitals	--	--	--	--	--	--	--	--	1	1	1	<1%	2	2	1	<1%
Private hospitals and clinics	--	--	--	--	--	--	--	--	1	1	1	<1%	1	1	1	<1%
Unions and associations	--	--	--	--	3	1	3	1%	1	1	1	<1%	--	--	--	--

Notes: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the 'unspecified' sector have been excluded.

What follows is an examination of the coverage of social sciences articles on two sets of data sources – the first based on WoS and Scopus combined, and the second based on Scopus, WoS and the NRDZ. The objective, as already stated in the previous sections, was to determine how the addition of NRDZ data changes the summary profile for the social sciences compared to when only Scopus and WoS data are used. From the comparison in Table 7.22, it can be seen that 550 out of 637 social sciences articles were indexed in Scopus and WoS, with the NRDZ accounting for 87 additional articles. These results mean that when it comes to the field of social sciences, the value of the indicators changes to a small extent as the NRDZ contributes a small number of articles that are not indexed in Scopus and WoS.

Table 7.22: Comparative profile of article output in social sciences, by national sector in the period 2012–2016

National sectors	***Based on Scopus and WoS (n=550)*** *[5 years; 110 articles per year]*				***Based on Scopus, WoS and NRDZ (n=637)*** *[5 years; 127 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	423	9	47	77%	507	9	47	80%
Government sector	64	32	2	12%	73	35	2	11%
NGO sector	50	25	2	9%	50	25	2	8%
INO sector	38	16	2	7%	38	16	2	6%
International research organisations	16	3	5	3%	16	3	5	3%
Inter-governmental organisations	14	5	3	3%	14	5	3	2%
International NGOs	10	8	1	2%	10	8	1	2%
International industry/businesses	--	--	--	--	--	--	--	--
Other national sectors	25	13	2	5%	25	13	2	4%
Private schools and tertiary institutions	14	5	3	3%	14	5	3	2%
Industry/businesses	8	5	2	1%	8	5	2	1%
Mission or faith-based hospitals	2	2	1	<1%	2	2	1	<1%
Private hospitals and clinics	1	1	1	<1%	1	1	1	<1%
Unions and associations	--	--	--	--	--	--	--	--

7.5.1 Co-authorship patterns of the most productive national sectors in the social sciences

This section now discusses the co-authorship patterns of the three most productive sectors in the social sciences. The relevant sectors are the university, government and NGO sectors. Table 7.23 below shows that between 1980 and 1990, the three sectors together produced a total of 213 social sciences articles. Of these, 71% were produced by the university sector on its own without any co-authorship with other Zimbabwean sectors or international authors. The government sector accounted for 14% of the total article output, also on its own without any co-authorship with other Zimbabwean sectors or international authors. Together the university and government sector, each producing research on its own, were responsible for 85% of the 213 articles in the first period. When only the last period is analysed, it is observed that the three sectors produced a total of 648 articles. Of these, 38% were produced by the university sector in collaboration with international authors, 37% were produced by the university sector on its own, without any co-authorship by other Zimnbadwean sectors or international authors. The NGO sector produced 8% of the total articles in the last period in collaboration with international authors and only 1% on its own, without any co-authorship by other Zimbabwean sectors or international authors. This indicates that in the last period, the NGO sector seldom produced articles on its own, but rather mainly through international co-authorship.

Table 7.23: Co-authorship patterns of the three most productive national sectors in social sciences, by socio-political period

Mutually exclusive classification 1: three most productive national sectors	**1980–1990 (n=290)**				**1991–1997 (n=415)**				**1998–2008 (n=722)**				**2009–2016 (n=533)**			
	Mutually exclusive classification 2: other national sectors and international sector				**Mutually exclusive classification 2: other national sectors and international sector**				**Mutually exclusive classification 2: other national sectors and international sector**				**Mutually exclusive classification 2: other national sectors and international sector**			
	Other national sectors only	**Interna-tional sector only**	**Other national sectors and interna-tional sector**	**Neither other national sectors nor interna-tional sector**	**Other national sectors only**	**Interna-tional sector only**	**Other national sectors and interna-tional sector**	**Neither other national sectors nor interna-tional sector**	**Other national sectors only**	**Interna-tional sector only**	**Other national sectors and interna-tional sector**	**Neither other national sectors nor interna-tional sector**	**Other national sectors only**	**Interna-tional sector only**	**Other national sectors and interna-tional sector**	**Neither other national sectors nor interna-tional sector**
University sector only	<1%	9%	0%	71%	0%	24%	0%	59%	2%	40%	2%	35%	1%	38%	2%	37%
Government sector only	0%	3%	0%	14%	0%	2%	0%	8%	0%	5%	<1%	3%	0%	5%	<1%	1%
NGO sector only	0%	0%	0%	2%	0%	<1%	0%	3%	0%	4%	0%	3%	0%	8%	<1%	1%
Both university sector and government sector	0%	0%	0%	<1%	0%	1%	0%	<1%	1%	2%	0%	<1%	0%	2%	<1%	2%
Both university sector and NGO sector	0%	0%	0%	0%	0%	<1%	0%	0%	0%	2%	0%	0%	0%	<1%	<1%	<1%
Both government sector and NGO sector	0%	0%	0%	0%	<1%	<1%	0%	0%	<1%	1%	0%	0%	0%	<1%	<1%	0%
All three sectors	0%	0%	0%	0%	0%	0%	0%	<1%	0%	0%	0%	0%	0%	0%	<1%	<1%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following two categories from Table 7.19: ‘INO sector’ and ‘other national sectors’.

7.5.2 Article output of the most productive Zimbabwean organisations in social sciences

This section now presents the article output of the organisations in each of the three productive sectors. Presented first are organisations in the university sector, followed by organisations in the government sector and the NGO sector. Lastly, the five most productive Zimbabwean organisations in the social sciences, across sectors, are identified and highlighted.

- ***University sector***

Table 7.24 shows that the University of Zimbabwe produced 100% of the total articles in the first period. The same university accounted for 98% of the total articles in the second period. In the third period, seven universities produced 272 articles. Of these articles, 86% were produced by the University of Zimbabwe. This was followed by the Midlands State University with a small share of 4%. The percentage contribution of the University of Zimbabwe dropped from 86% in the third period to 47% in the last period, while the share by the Midlands State University increased from 4% in the third period to 19% in the last period.

Table 7.24: Article output in social sciences, by university and socio-political period

Zimbabwean universities	1980-1990 (n=173)		1991-1997 (n= 214)		1998-2008 (n=272)		2009-2016 (n=535)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	173	100%	210	98%	233	86%	254	47%
Midlands State University	--	--	--	--	11	4%	102	19%
Great Zimbabwe University	--	--	--	--	5	2%	49	9%
Bindura University of Science Education	--	--	--	--	14	5%	41	8%
National University of Science and Technology	--	--	5	2%	8	3%	37	7%
Zimbabwe Open University	--	--	--	--	7	3%	37	7%
Chinhoyi University of Technology	--	--	--	--	1	<1%	25	5%
Harare Institute of Technology	--	--	--	--	--	--	9	2%
Lupane State University	--	--	--	--	--	--	4	1%

Figure 7.12 shows the collaborative trends and patterns of the University of Zimbabwe in social sciences research. It is observed in the figure that the percentage of articles produced through single authorship decreased over time, while both international and national collaboration

increased. For instance, articles produced through single authorship dropped from 72% in the first period to 21% in the last period. When only the last period is considered, it can be seen that articles were equally produced through single authorship (21%), national collaboration only (23%), and both international and national collaboration (22%). The majority of the articles were produced through international collaboration only (34%).

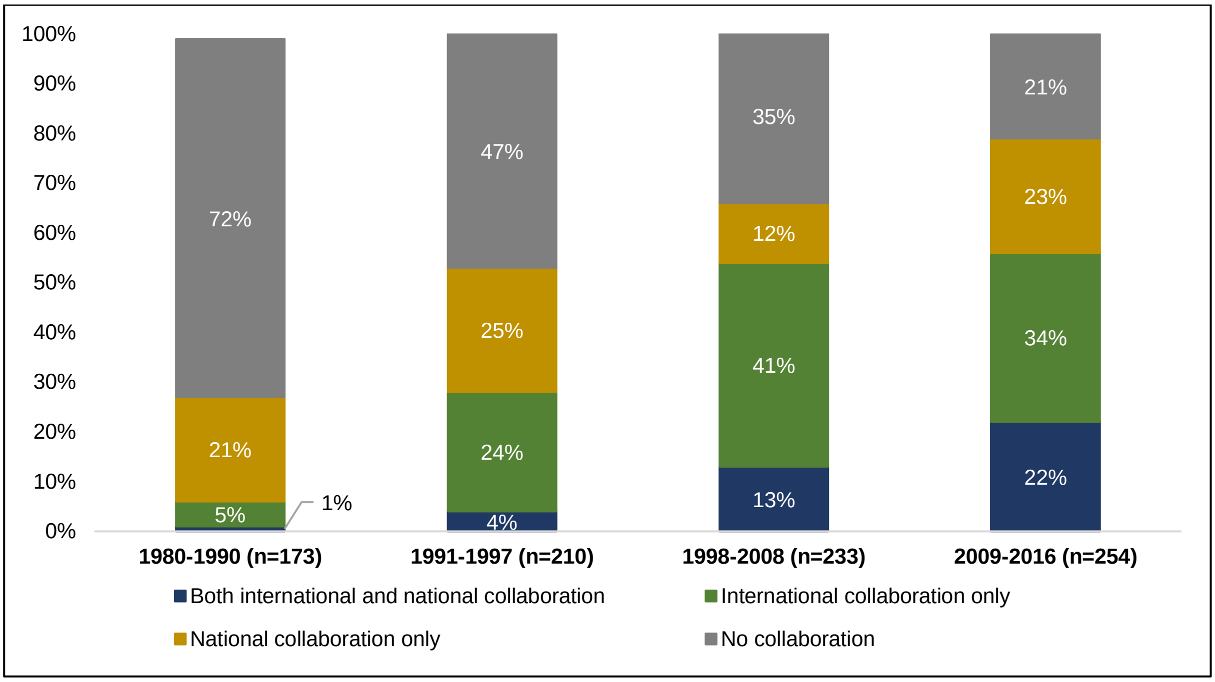

Figure 7.12: National versus international collaboration of the University of Zimbabwe in social sciences, by socio-political period

- ***Government sector***

When analysing the article output from organisations in the government sector (Table 7.25), the Ministry of Health and Child Care emerged as the largest producer of articles in the social sciences, with contributions of 22%, 29%, 31% and 21% articles across the four periods, respectively. The list of organisations contributing to social sciences research within the Ministry of Health and Child Care are provided in Appendix 12. It is observed in the appendix that the National Institute of Health Research and the Zimbabwe National Family Planning Council made significant contributions in the first three periods. The Ministry of Health and Child Care as a distinct organisation dominated the last period.

Table 7.25 further shows that in the last period, the Zimbabwe Parks and Wildlife Management authority made a noticeable contribution of 15%, followed by the Ministry of Lands, Agriculture and Rural Settlement with a contribution of 12%.

Table 7.25: Article output in social sciences, by government organisation and socio-political period

Zimbabwean organisations in government sector	1980-1990 (n=37)		1991-1997 (n= 31)		1998-2008 (n=42)		2009-2016 (n=535)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Ministry of Health and Child Care	8	22%	9	29%	13	31%	15	21%
Zimbabwe Parks and Wildlife Management Authority	1	3%	--	--	5	12%	11	15%
Ministry of Lands, Agriculture and Rural Settlement	7	19%	4	13%	3	7%	9	12%
Zimbabwe National Statistics Agency (ZIMSTAT)	2	5%	1	3%	1	2%	5	7%
Morgenster Teachers College	--	--	--	--	--	--	3	4%
National Archives of Zimbabwe	--	--	--	--	--	--	3	4%
Research Council of Zimbabwe	--	--	--	--	--	--	2	3%
Reserve Bank of Zimbabwe	--	--	--	--	--	--	2	3%
Zimbabwe Council for Higher Education	--	--	--	--	--	--	2	3%
Zimbabwe Revenue Authority (ZIMRA)	--	--	--	--	--	--	2	3%
Ministry of Primary and Secondary Education	5	14%	1	3%		0%	1	1%
Ministry of Public Service, Labour and Social Welfare	--	--	--	--	2	5%	1	1%
Ministry of Women's Affairs, Gender and Community Development	2	5%	1	3%		0%	1	1%
Hillside Teachers College	--	--	--	--	--	--	1	1%
Environmental Management Agency (EMA)	--	--	--	--	--	--	1	1%
Fletcher High School	--	--	--	--	--	--	1	1%
Harare City Council	--	--	--	--	--	--	1	1%
Masvingo City Council	--	--	--	--	--	--	1	1%
Gweru Polytechnical College	--	--	--	--	--	--	1	1%
Ministry of Small and Medium Enterprises and Cooperative Development	--	--	--	--	--	--	1	1%
Ministry of Mines and Mining Development	--	--	--	--	--	--	1	1%
Murehwa High School	--	--	--	--	--	--	1	1%
Belvedere Technical Teachers College	--	--	--	--	--	--	1	1%
National Gallery of Zimbabwe	--	--	--	--	--	--	1	1%
National Museums and Monuments of Zimbabwe (NMMZ)	--	--	--	--	--	--	1	1%
Scientific and Industrial Research and Development Centre (SIRDC)	--	--	--	--	--	--	1	1%
Social Welfare Department	--	--	--	--	--	--	1	1%
Upper Manyame Subcatchment Council	--	--	--	--	--	--	1	1%
Urban Development Corporation (UDCORP)	--	--	--	--	--	--	1	1%
Zimbabwe Broadcasting Corporation	--	--	--	--	--	--	1	1%
Zimbabwe National Army	--	--	--	--	--	--	1	1%
Zimbabwe National Defence College	--	--	--	--	--	--	1	1%
Zimbabwe Prisons and Correctional Service	--	--	--	--	--	--	1	1%
Zimbabwe School of Mines	--	--	--	--	--	--	1	1%
Murewa Local Government	--	--	--	--	--	--	1	1%
Zimbabwe Electricity Supply Authority	--	--	--	--	4	10%	--	--
Forestry Commision of Zimbabwe - Forest Research Centre	--	--	--	--	4	10%	--	--
Ministry of Transport and Infrastructural Development	--	--	--	--	2	5%	--	--
Ministry of Environment, Water and Climate	--	--	--	--	2	5%	--	--

Zimbabwean organisations in government sector	1980-1990 (n=37)		1991-1997 (n= 31)		1998-2008 (n=42)		2009-2016 (n=535)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Zimbabwe Institute of Development Studies (ZIDS)	3	8%	4	13%	1	2%	--	--
Public Service Commission (PSC)	--	--	--	--	1	2%	--	--
Natural History Museum of Zimbabwe	--	--	--	--	1	2%	--	--
Mkoba Teachers College	--	--	--	--	1	2%	--	--
Bulawayo Public Library	--	--	--	--	1	2%	--	--
Belvedere Technical Teachers College	--	--	--	--	1	2%	--	--
Zimbabwe National Army	--	--	5	16%	--	--	--	--
Ministry of Local Government, Public Works and National Housing	--	--	2	6%	--	--	--	--
National Archives of Zimbabwe	3	8%	1	3%	--	--	--	--
Zimbabwe Broadcasting Corporation	--	--	1	3%	--	--	--	--
Ministry of Foreign Affairs	--	--	1	3%	--	--	--	--
Bulawayo Polytechnic College	--	--	1	3%	--	--	--	--
Zimbabwe Development Bank	2	5%	--	--	--	--	--	--
Gweru City Council	2	5%	--	--	--	--	--	--
Posts and Telecommunications Corporation of Zimbabwe	1	3%	--	--	--	--	--	--
Bromley Ruwa Rural Council Clinic	1	3%	--	--	--	--	--	--

- ***NGO sector***

The article output from the NGO sector is analysed in Table 7.26 below. The results in the table reveal that the number of NGOs contributing to social science research grew over time: from three organisations in the first period to 30 in the last period. The largest contribution of the article share in the last period came from the Biomedical Research and Training Institute. During this period, the institute produced 37% of the total articles, while the remainder of the NGOs each produced percentage shares of less than 10%.

Table 7.26: Article output in social sciences, by NGO and socio-political period

Zimbabwean organisations in NGO sector	1980-1990 (n=4)		1991-1997 (n= 13)		1998-2008 (n=33)		2009-2016 (n=75)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Biomedical Research and Training Institute	--	--			6	18%	28	37%
African Institute for Agrarian Studies (AIAS)	--	--			2	6%	6	8%
Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR)	--	--	--	--	--	--	5	7%
Dialogue on Shelter for the Homeless in Zimbabwe Trust	--	--	--	--	1	3%	4	5%
Centre for Research and Development	--	--	--	--	--	--	4	5%
Family AIDS Caring Trust	--	--	2	15%	6	18%	3	4%
Diocese of Mutare Community Care Programme (DOMCCP)	--	--	--	--	--	--	3	4%
Training and Research Support Centre (TARSC)	--	--	--	--	2	6%	2	3%
National Association of Non Governmental Organisations (NANGO)	--	--	--	--	--	--	2	3%
Ruzivo Trust	--	--	--	--	--	--	2	3%
St Giles Medical Rehabilitation Centre	--	--	1	8%	--	--	1	1%
Hellen Army, Harare	--	--	--	--	--	--	1	1%
Maranatha Orphans Care Trust	--	--	--	--	--	--	1	1%
Faith Ministries Zimbabwe	--	--	--	--	--	--	1	1%
Centre for Natural Resource Governance (CNRG)	--	--	--	--	--	--	1	1%
Grace To Heal	--	--	--	--	--	--	1	1%
Community Technology Development Trust (CTDT)	--	--	--	--	--	--	1	1%
AFRICAID Zvandiri	--	--	--	--	--	--	1	1%
Kubatana Trust of Zimbabwe	--	--	--	--	--	--	1	1%
Zimbabwe Red Cross Society	--	--	--	--	--	--	1	1%
National Blood Service Zimbabwe	--	--	--	--	--	--	1	1%
Pastoral Care and Counseling Services	--	--	--	--	--	--	1	1%
Public Policy Research Institute of Zimbabwe (PPRIZ)	--	--	--	--	--	--	1	1%
Sebakwe Black Rhino Trust	--	--	--	--	--	--	1	1%
Shanduko Centre For Agrarian & Environment Research	--	--	--	--	--	--	1	1%
Shurugwi Partners	--	--	--	--	--	--	1	1%
Tree of Life	--	--	--	--	--	--	1	1%
Zimbabwe Association for Crime Prevention and Rehabilitation of the Offender (ZACRO)	--	--	--	--	--	--	1	1%
Zimbabwe Cricket	--	--	--	--	--	--	1	1%
Humanitarian Information Facilitation Centre (HIFC)	--	--	--	--	--	--	1	1%
Mass Public Opinion Institute	--	--			3	9%	--	--
Amani Trust	--	--			3	9%	--	--
Shanduko Centre For Agrarian & Environment Research	--	--	--	--	2	6%	--	--
African Farmers Organic Research and Training (AFFOREST)	--	--	--	--	1	3%	--	--
Kubatana Trust of Zimbabwe	--	--	--	--	1	3%	--	--
Media support - MISA Zimbabwe	--	--	--	--	1	3%	--	--
Midlands AIDS Caring Organisation (MACO)	--	--	--	--	1	3%	--	--

Zimbabwean organisations in NGO sector	**1980-1990 (n=4)**		**1991-1997 (n= 13)**		**1998-2008 (n=33)**		**2009-2016 (n=75)**	
	Number of articles	**% articles**	**Number of articles**	**% articles**	**Number of articles**	**% articles**	**Number of articles**	**% articles**
Public Policy Research Institute of Zimbabwe (PPRIZ)	--	--	--	--	1	3%	--	--
Seventh-day Adventist Church	--	--	--	--	1	3%	--	--
The Zambezi Society	--	--	--	--	1	3%	--	--
Sapes Trust	--	--	2	15%	--	--	--	--
Christian Life Centre	--	--	2	15%	--	--	--	--
Zimbabwe Women's Resource Centre and Network (ZWRCN)	--	--	1	8%	--	--	--	--
Zimbabwe Institute of Systemic Therapy (CONNECT)	--	--	1	8%	--	--	--	--
Zimbabwe Book Development Council	--	--	1	8%	--	--	--	--
Women and AIDS Support Network Zimbabwe (WASN)	--	--	1	8%	--	--	--	--
National Association of Social Workers Zimbabwe (NASW-Z)	--	--	1	8%	--	--	--	--
Musasa Project	--	--	1	8%	--	--	--	--
Matabeleland AIDS Council	--	--	1	8%	--	--	--	--
Elim Pentecostal Church of Zimbabwe	--	--	1	8%	--	--	--	--
Bulawayo Legal Projects Centre	--	--	1	8%	--	--	--	--
Hostes Nicolle Institute for Wildlife Research	2	50%	--	--	--	--	--	--
Volunteer Zimbabwe, Volunteering and charity work in Zimbabwe (VSO)	1	25%	--	--	--	--	--	--
The Computer Society of Zimbabwe	1	25%	--	--	--	--	--	--

It is important to note that the collaboration trends of organisations in the government and NGO sector were not analysed because of the low number of articles produced by organisations.

- ***The seven most research-productive organisations in social sciences***

Lastly, a summary profile of the percentage contributions of the top-producing organisations in the social sciences between 2009 and 2016 was compiled. Based on Tables 7.24, 7.25 and 7.26, the seven most productive Zimbabwean organisations in the last period, across all three productive sectors, were identified. Table 7.27 shows that between 2009 and 2016, the University of Zimbabwe, with a percentage contribution of 36%, produced the majority of the articles in the field of social sciences in the country. It was followed by the Midlands State University with a percentage contribution of 14%, and the Great Zimbabwe University with 7%. When only the output from the University of Zimbabwe was analysed, it was found that the university accounted for 47% of all social sciences articles within the university sector, and that 56% of its articles were produced through international co-authorship. Although the percentage contribution of the Biomedical Research and Training Institute was less than 5% of the country's article output, it is the only organisation that produced its articles exclusively through international co-authorship.

Table 7.27: Summary profile of the seven most research-productive organisations in social sciences, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	254	36%	47%	56%
Midlands State University (University sector)	102	14%	19%	29%
Great Zimbabwe University (University sector)	49	7%	9%	47%
Bindura University of Science Education (University sector)	41	6%	8%	39%
National University of Science and Technology (University sector)	37	5%	7%	38%
Zimbabwe Open University (University sector)	37	5%	7%	57%
Biomedical Research and Training Institute (NGO sector)	28	4%	37%	100%

7.6 Article output in the engineering and technologies by the different national sectors

The focus now shifts to the field of engineering and technologies. Table 7.28 shows the article output of the national sectors in engineering and technologies, by socio-political field. For each sector in any period, the following four indicators of research production are reported:

- The total number of articles produced by the sector;
- The number of unique (non-duplicate) Zimbabwean organisations responsible for the article output in the sector;
- The average number of articles per Zimbabwean organisation in the sector; and
- The sector's contribution (percentage share) to the total article output in the relevant period.

It is shown in Table 7.28 that the average number of articles per year in engineering and technologies, as produced by the different Zimbabwean sectors, increased steadily from five articles per year in the first period to 17 articles per year in the third period, and then dropped slightly to 14 articles per year in the last period. Table 7.28 shows that in the first period, out of a total 51 articles, the majority (61%) were produced by the university sector. This is followed by the government sector with a percentage contribution of 20%. The industry and business sector came third with a low but noticeable contribution of 8%. In the third period, 187 articles were produced. Of these, 80% were accounted for by the university sector. The government sector was responsible for 15% of the total articles in the third period, while the business and industry sector produced 8% of the total articles in the same period. The presence of international businesses and companies is only seen in the first and second periods with 8% and 7%, respectively.

The two most productive sectors in the last period were the university sector, with a percentage contribution of 88%, and the government sector with a contribution of 10%. Overall, these two sectors displayed different trends. While the article output by the university sector increased from 61% in the first period to 88% in the last period, the contribution by the government sector decreased from 20% in the first period to 10% in the last period.

Table 7.28: Summary profile of article output in engineering and technologies, by national sector and socio-political period

National sectors	1980–1990 (n=51) [11 years; 5 articles per year]				1991–1997 (n=104) [7 years; 15 articles per year]				1998–2008 (n=187) [11 years; 17 articles per year]				2009–2016 (n=111) [8 years; 14 articles per year]			
	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period
University sector	31	1	31	61%	79	2	40	76%	150	4	38	80%	98	8	12	88%
Government sector	10	7	1	20%	6	5	1	6%	28	12	2	15%	11	8	1	10%
NGO sector	--	--	--	--	--	--	--	--	2	2	1	1%	2	2	1	2%
INO sector	4	3	1	8%	14	6	2	13%	10	7	1	5%	5	5	1	5%
International research organisations	--	--	--	--	--	--	--	--	2	2	1	1%	3	3	1	3%
International NGOs	--	--	--	--	7	3	2	7%	7	4	2	4%	1	1	1	1%
Inter-governmental organisations	--	--	--	--	--	--	--	--	1	1	1	1%	1	1	1	1%
International industry/businesses	4	3	1	8%	7	3	2	7%	--	--	--	--	--	--	--	--
Other national sectors	5	4	1	10%	5	3	2	5%	17	13	1	9%	3	3	1	3%
Industry/businesses	4	3	1	8%	5	3	2	5%	15	11	1	8%	3	3	1	3%
Private schools and tertiary institutions	--	--	--	--	--	--	--	--	1	1	1	1%	--	--	--	--
Unions and associations	--	--	--	--	--	--	--	--	1	1	1	1%	--	--	--	--
Private hospitals and clinics	1	1	1	2%	--	--	--	--	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the 'unspecified' sector have been excluded.

Having presented the article output by sector in the field, this section provides an analysis of the coverage of engineering and technologies articles in the two sets of data sources – the WoS and Scopus combined, and the data set based on Scopus, WoS and the NRDZ. Table 7.29 below shows the results of the comparative profile of article output by sector in engineering and technologies, in the last period. It is seen in the table that the entire article output of Zimbabwe in engineering and technologies (87 out of 88) was indexed in Scopus and WoS, with the NRDZ accounting for only one article. These results, therefore, indicate that no significant change can be observed when comparing the indicators derived from Scopus and WoS data with the indicators based on all three data sources together.

Table 7.29: Comparative profile of article output in engineering and technologies, by national sector in the period 2012–2016

National sectors	***Based on Scopus and WoS (n=87)*** *[5 years; 17 articles per year]*				***Based on Scopus, WoS and NRDZ (n=88)*** *[5 years; 18 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	79	8	10	91%	80	8	10	91%
Government sector	8	6	1	9%	8	6	1	9%
NG sector	1	1	1	1%	1	1	1	1%
INO sector	3	3	1	3%	3	3	1	3%
International research organisations	1	1	1	1%	1	1	1	1%
International NGOs	1	1	1	1%	1	1	1	1%
Inter-governmental organisations	1	1	1	1%	1	1	1	1%
International industry/businesses	--	--	--	--	--	--	--	--
Other national sectors	2	2	1	2%	2	2	1	2%
Industry/businesses	2	2	1	2%	2	2	1	2%
Private schools and tertiary institutions	--	--	--	--	--	--	--	--
Private hospitals and clinics	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--
Unions and associations	--	--	--	--	--	--	--	--

7.6.1 Co-authorship patterns of the most productive national sectors in engineering and technologies

In this section, the focus shifts to the co-authorship patterns of the two most productive sectors in the last period; namely, the university and government sectors. For the purpose of the co-authorship analysis, two new variables were created and subsequently cross-tabulated (as described in Section 7.3.2 above). Table 7.30 presents the results of the cross-tabulation between the two variables, thereby showing the concentrations of co-authorship in each of the four socio-political periods, together with an indication of the nature of the co-authorship.

In the first period, the university and government sectors produced a total of 41 articles. Of these, 66% were produced by the university sector on its own, without any co-authorship with other Zimbabwean sectors or international organisations. The government sector produced 22% of its article output on its own, without any co-authorship with other Zimbabwean sectors or international organisations. In the last period, the two sectors produced a total of 103 articles. The university sector accounted for 55% of this total in collaboration with international organisations. The government sector produced 31% of the total output on its own, without any co-authorship by other Zimbabwean sectors or international organisations. Together, the university and government sectors, each producing articles in collaboration with international organisations, were responsible for 58% of the 103 articles in the last period.

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Table 7.30: Co-authorship patterns of the two most productive national sectors in engineering and technologies, by socio-political period

Mutually exclusive classification 1: two most productive national sectors	1980–1990 (n=41)				1991–1997 (n=84)				1998–2008 (n=164)				2009–2016 (n=103)			
	Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector			
	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector
University sector only	0%	10%	0%	66%	0%	29%	0%	64%	1%	42%	3%	38%	1%	55%	2%	31%
Government sector only	0%	2%	0%	22%	0%	1%	0%	5%	0%	5%	0%	5%	1%	3%	0%	1%
Both sectors	0%	0%	0%	0%	0%	0%	1%	0%	1%	2%	1%	2%	0%	2%	0%	4%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following three categories from Table 7.28: ‘NGO sector’, ‘INO sector’ and ‘other national sectors’.

7.6.2 Article output of the most productive Zimbabwean organisations in engineering and technologies

This section presents an analysis of the article output of the organisations in each of the productive sectors discussed in the previous section (i.e. the university and government sectors). Presented first are organisations in the university sector, followed by those in the government sector. Lastly, an article summary profile of the top-producing organisations in engineering and technologies is provided.

- ***University sector***

It can been seen in Table 7.31 that the University of Zimbabwe produced all 31 articles in the first period. In the second period, the University of Zimbabwe and the National University of Science and Technology produced 79 articles, with a percentage contribution of 81% and 19%, respectively. While the percentage contribution of the National University of Science and Technology increased from 19% to 40% in the third period, the contribution by the University of Zimbabwe dropped from 81% to 59%. In the last period, eight universities were responsible for 98 articles. The University of Zimbabwe accounted for 49% of this total. In second place was the National University of Science and Technology with a percentage contribution of 16%, followed by the Harare Institute of Technology at 14%.

Table 7.31: Article output in engineering and technologies, by university and socio-political period

Zimbabwean universities	1980-1990 (n=31)		1991-1997 (n= 79)		1998-2008 (n=150)		2009-2016 (n=98)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	31	100%	64	81%	89	59%	48	49%
National University of Science and Technology	--	--	15	19%	60	40%	16	16%
Harare Institute of Technology	--	--	--	--	--	--	14	14%
Chinhoyi University of Technology	--	--	--	--	1	1%	12	12%
Bindura University of Science Education	--	--	--	--	7	5%	7	7%
Midlands State University	--	--	--	--	--	--	12	7%
Great Zimbabwe University	--	--	--	--	--	--	2	2%
Lupane State University	--	--	--	--	--	--	1	1%

Figure 7.13 provides an analysis of the collaboration trends and patterns of the University of Zimbabwe in the field of engineering and technologies. As can be seen, there was a significant drop in the percentage contribution of articles produced through single authorship. It can also be seen that there was an increase in the percentage contribution of articles produced through national collaboration only. For example, articles produced through national collaboration only increased from 0% in the first period to 42% in the last period, contributing the largest share of articles in that period. The share of articles produced through international collaboration only increased from 13% in the first period to 34% in the third period, and dropped to 21% in the last period.

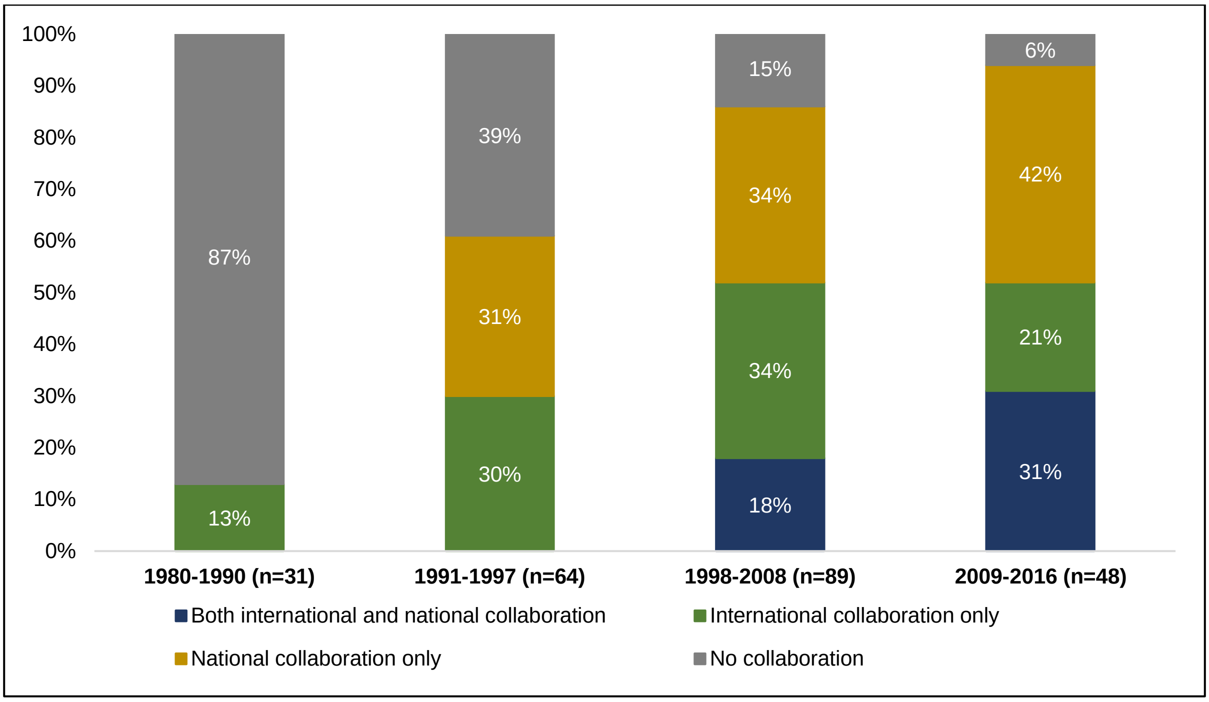

Figure 7.13: National versus international collaboration of the University of Zimbabwe in engineering and technologies, by socio-political period

Figure 7.14 shows the collaboration trends and patterns of the National University of Science and Technology. Here, it can be seen that there was a systematic decrease in the percentage share of articles produced through single authorship and those produced through national collaboration only. It can also be seen that there was a significant increase in articles produced through international collaboration only and through both national collaboration and international collaboration. For example, articles produced through international collaboration increased from 20% in the second period to 44% in the last period, while articles produced through single authorship decreased from 53% in the third period to 6% in the last period.

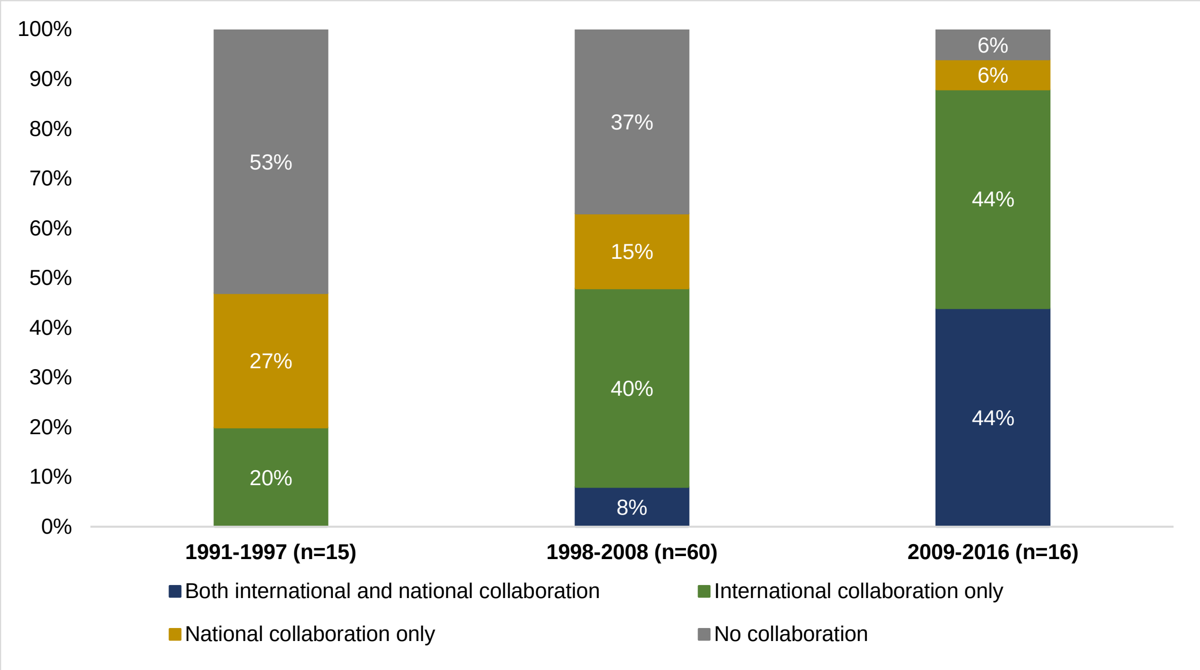

Figure 7.14: National versus international collaboration of the National University of Science and Technology in engineering and technologies, by socio-political period

- ***Government sector***

Table 7.32 provides a list of all government organisations producing engineering and technologies articles from 1980 to 2016 in Zimbabwe. It is observed in the table that the article output from the organisations in the sector was relatively low throughout the period of study. In the last period, the most productive organisation in the sector was the Scientific and Industrial Research and Development Centre (SIRDC), although with only five articles in a period of eight years. Seven other organisations, as shown in the table, all produced one article each.

Table 7.32: Article output in engineering and technologies, by government organisation and socio-political period

Zimbabwean organisations in government sector	1980-1990 (n=10)		1991-1997 (n= 6)		1998-2008 (n=28)		2009-2016 (n=11)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
Scientific and Industrial Research and Development Centre (SIRDC)	--	--	--	--	6	21%	5	45%
Zimbabwe Electricity Supply Authority	--	--	--	--	5	18%	1	9%
Ministry of Lands, Agriculture and Rural Settlement	2	20%	2	33%	1	4%	1	9%
Ministry of Health and Child Care	2	20%	--	--	--	--	1	9%
Harare Polytechnic College	2	20%	--	--	--	--	1	9%
Ministry of Mines and Mining Development	--	--	1	17%	--	--	1	9%
Zimbabwe National Water Authority	--	--	--	--	--	--	1	9%
Upper Manyame Subcatchment Council	--	--	--	--	--	--	1	9%
Meteorological Services Department of Zimbabwe	--	--	--	--	6	21%	--	--
Ministry of Transport and Infrastructural Development	1	10%	--	--	3	11%	--	--
Shabanie Mine Zvishavane	--	--	1	17%	2	7%	--	--
Zimbabwe Power Company Limited	--	--	--	--	1	4%	--	--
Zimbabwe Parks and Wildlife Management Authority	--	--	--	--	1	4%	--	--
Mkoba Teachers College	--	--	--	--	1	4%	--	--
Ministry of Local Government, Public Works and National Housing	--	--	--	--	1	4%	--	--
Ministry of Energy and Power Development	--	--	--	--	1	4%	--	--
Forestry Commission of Zimbabwe - Forest Research Centre	--	--	--	--	1	4%	--	--
Telecommunications Corporation	--	--	1	17%	--	--	--	--
Department of Natural Resources	--	--	1	17%	--	--	--	--
Zimbabwe School of Mines	1	10%	--	--	--	--	--	--
National Railways of Zimbabwe	1	10%	--	--	--	--	--	--
Ministry of Environment, Water and Climate	1	10%	--	--	--	--	--	--

- ***The four most research-productive organisations in engineering and technologies***

Finally, based on Tables 7.31 and 7.32, the four most productive Zimbabwean organisations in the last period, could be identified. The four organisations are presented in Table 7.33. The table shows the total number of articles produced by each organisation. The totals are further expressed as a percentage of the total number of articles in Zimbabwe in the last period, and as a percentage of the total number of articles in the sector to which the organisation belongs.

It is also indicated what percentage of an organisation's article output involved international co-authorship.

Table 7.33: Summary profile of the four most research-productive organisations in engineering and technologies, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	48	43%	49%	52%
National University of Science and Technology (University sector)	16	14%	16%	88%
Harare Institute of Technology (University sector)	14	13%	14%	100%
Chinhoyi University of Technology (University sector)	12	11%	12%	17%

Table 7.33 shows that the University of Zimbabwe, with a percentage contribution of 43%, produced the majority of articles in the field of engineering and technologies in the country. It was followed by the National University of Science and Technology with a percentage contribution of 14%, and the Harare institute of Technology at 13%. When only the output from the University of Zimbabwe was analysed, it was found that the university accounted for 49% of all engineering and technologies articles within the university sector, and that 52% of its articles were produced through international co-authorship. The table also shows that the Harare Institute of Technology, which accounted for 13% of the articles in the country, was responsible for 14% of the articles within the university sector, and that 100% of its articles were produced through international co-authorship.

7.7 Article output in the humanities by the different national sectors

Presented lastly in this chapter is the article output of the national sectors in humanities, by socio-political period. Table 7.34 illustrates this output. For each sector in any socio-political period, the four indicators of research production are reported. The table shows that the average number of articles produced by the different Zimbabwean sectors in humanities decreased from seven articles per year in the first period to an average of six articles per year in the second period. The average number of articles per year increased to eight in the third period and reached a high of 30 articles per year in the last period. This increase could be attributed to more organisations emerging to produce research. For example, in the first period, only one university contributed to the article output whereas eight universities contributed to the article output in the last period. Similarly, in the first period, only one organisation in the government sector contributed to the article output, whereas in last period the corresponding figure was 15.

Table 7.34 further shows that the university sector was responsible for the majority of humanities articles in the period under review. The share of articles by the sector increased from 71% in the first period to 85% in the last. The government sector made very small contributions of 5% and 7% in the first and second periods, respectively, and a constant share of 8% in the third and last periods.

Table 7.34: Summary profile of article output in humanities, by national sector and socio-political period

National sectors	1980–1990 (n=73) [11 years; 7 articles per year]				1991–1997 (n=44) [7 years; 6 articles per year]				1998–2008 (n=92) [11 years; 8 articles per year]				2009–2016 (n=241) [8 years; 30 articles per year]			
	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period	Number of articles	Number of organi-sations	Average articles per organi-sation	% of articles in period
University sector	52	1	52	71%	32	1	32	73%	69	4	17	75%	204	8	26	85%
Government sector	4	1	4	5%	3	2	2	7%	7	5	1	8%	20	15	1	8%
NGO sector	1	1	1	1%	1	1	1	2%	5	4	1	5%	4	4	1	2%
Other national sectors	--	--	--	--	3	1	3	7%	6	4	2	7%	15	7	2	6%
Private schools and tertiary institutions	--	--	--	--	3	1	3	7%	6	4	2	7%	13	5	3	5%
Industry/businesses	--	--	--	--	--	--	--	--	--	--	--	--	2	2	1	1%
Private hospitals and clinics	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unions and associations	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
INO sector	4	4	1	5%	3	3	1	7%	6	6	1	7%	6	5	1	2%
International NGOs	1	1	1	1%	--	--	--	--	3	3	1	3%	6	5	1	2%
Inter-governmental organisations	3	3	1	4%	3	3	1	7%	2	2	1	2%	--	--	--	--
International industry/businesses	--	--	--	--	--	--	--	--	1	1	1	1%	--	--	--	--
International research organisations	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes: The percentages per sector exceed 100% because some articles involve co-authorship between different sectors. Articles classified solely within the ‘unspecified’ sector have been excluded.

Table 7.35 incorporates the NRDZ data in the summary profile for the humanities. As mentioned previously, the objective was to determine how the addition of NRDZ data changes the summary profile for the humanities compared to when only Scopus and WoS data are used. The results of the comparison show that the majority of articles in the humanities (180 out of 210) were indexed in Scopus and WoS, with only 30 additional articles indexed in the NRDZ. Few changes can therefore be observed when comparing the indicators derived from Scopus and WoS data with the indicators based on all three data sources.

Table 7.35: Comparative profile of article output in humanities, by national sector in the period 2012–2016

National sectors	*Based on Scopus and WoS (n=180)* *[5 years; 36 articles per year]*				*Based on Scopus, WoS and NRDZ (n=210)* *[5 years; 42 articles per year]*			
	Number of articles	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**	**Number of articles**	**Number of organi-sations**	**Average articles per organi-sation**	**% of articles in period**
University sector	153	8	19	85%	183	8	19	87%
Government sector	18	13	1	10%	18	13	1	9%
NGO sector	2	2	1	1%	2	2	1	1%
Other national sectors	9	5	2	5%	9	5	2	4%
Private schools and tertiary institutions	8	4	2	4%	8	4	2	4%
Industry/businesses	1	1	1	1%	1	1	1	0%
Private hospitals and clinics	--	--	--	--	--	--	--	--
Mission or faith-based hospitals	--	--	--	--	--	--	--	--
Unions and associations	--	--	--	--	--	--	--	--
INO sector	3	3	1	2%	3	3	1	1%
International NGOs	3	3	1	2%	3	3	1	1%
International industry/businesses	--	--	--	--	--	--	--	--
Inter-governmental organisations	--	--	--	--	--	--	--	--
International research organisations	--	--	--	--	--	--	--	--

7.7.1 Co-authorship patterns of the university sector in humanities

The co-authorship patterns of the university sector (i.e. the most productive sector in the field of the humanities) are provided in Table 7.36. As can be seen, in the first period the university sector produced a total of 52 articles. Of these, 92% were produced with neither other national sectors nor the international sector, and 8% were produced through international co-authorship. In the third period, the university sector produced a total of 69 articles. Of these, 80% were produced without any co-authorship by other Zimbabwean sectors or international authors, and 19% were produced in collaboration with international co-authors. However, in the last period, the sector produced 34% of its articles in collaboration with international co-authors. The remaining 60% were produced by the sector on its own without any co-authorship by other Zimbabwean sectors or international authors. Compared to other fields in the study, the university sector produced the majority of articles in the humanities on its own without any co-authorship by other Zimbabwean sectors or international authors.

Table 7.36: Co-authorship patterns of the two most productive national sectors in humanities, by socio-political period

Most productive national sector	1980–1990 (n=52)				1991–1997 (n=32)				1998–2008 (n=69)				2009–2016 (n=204)			
	Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector				Mutually exclusive classification 2: other national sectors and international sector			
	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector	Other national sectors only	Interna-tional sector only	Other national sectors and interna-tional sector	Neither other national sectors nor interna-tional sector
University sector	0%	8%	0%	92%	3%	9%	0%	88%	0%	19%	1%	80%	3%	34%	2%	60%
Total	**100%**				**100%**				**100%**				**100%**			

Note: The category ‘other national sectors’ combines the following four categories from Table 7.34: ‘Government sector’, ‘NGO sector’, ‘other national sectors’ and ‘INO sector’.

7.7.2 Article output of the university sector in humanities

The previous section presented an analysis of article output in the humanities by sector, and the co-authorship patterns of the most productive sector in the field – in this case, the university sector. This section presents the article output of the universities that contributed to the article output in the field. Following this, the three most productive universities are identified and highlighted.

Table 7.37 shows that the University of Zimbabwe accounted for 100% of the articles in the humanities in the first and second periods. The contribution by the university decreased to 86% in the third period and decreased further to 49% in the last period. The decrease in the percentage share of articles produced by the University of Zimbabwe could be attributed to more universities also emerging to produce articles. For example, three more universities contributed to the article output in the third period. In the last period, seven more universities, in addition to the University of Zimbabwe, contributed articles in the humanities. The table shows that in the last period, eight universities produced a total of 204 articles. Of these articles, 99 (49%) were produced by the University of Zimbabwe and 59 (29%) were accounted for by the Midlands State University.

Table 7.37: Article output in humanities, by university and socio-political period

Zimbabwean universities	1980-1990 (n=52)		1991-1997 (n= 32)		1998-2008 (n=69)		2009-2016 (n=204)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
University of Zimbabwe	52	100%	32	100%	59	86%	99	49%
Midlands State University	--	--	--	--	8	12%	59	29%
Great Zimbabwe University	--	--	--	--	1	1%	37	18%
National University of Science and Technology	--	--	--	--	1	1%	4	2%
Zimbabwe Open University	--	--	--	--	--	--	4	2%
Chinhoyi University of Technology	--	--	--	--	--	--	3	1%
Lupane State University	--	--	--	--	--	--	3	1%
Harare Institute of Technology	--	--	--	--	--	--	1	<1%

Figure 7.15 provides an analysis of the collaboration trends and patterns of the University of Zimbabwe in the field of humanities. The figure shows that the percentage share of articles

produced through single authorship decreased from 88% in the first period to 45% in the last period. Although the number of articles produced through single authorship decreased, a noticeable share of almost half the articles was still produced through single authorship. Figure 7.15 further shows that the percentage contribution of articles produced through international collaboration only increased steadily, from 4% in the first period to 26% in the last period.

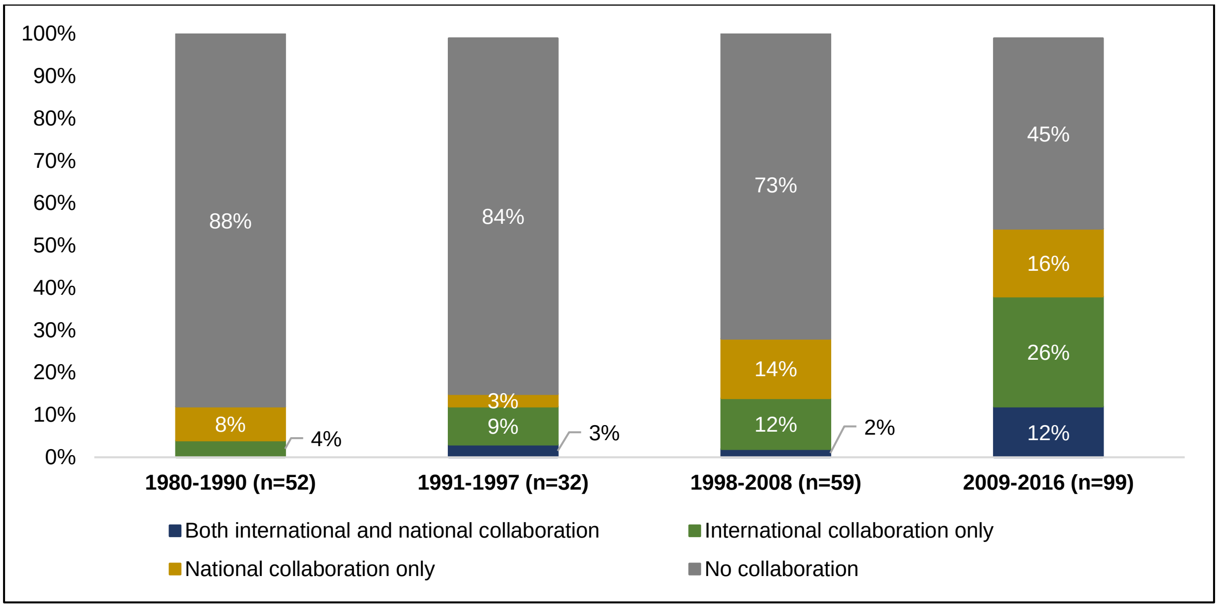

Figure 7.15: National versus international collaboration of the University of Zimbabwe in humanities, by socio-political period

- ***The three most research-productive organisations in humanities***

This section presents a summary profile of the percentage contributions of the top-producing organisations in the humanities between 2009 and 2016. Table 7.38 shows that between 2009 and 2016, the University of Zimbabwe produced 41% of the total articles in the humanities in the country. It accounted for 49% of the article output in the university sector, and 38% of the articles were produced through international co-authorship. The table further shows that the Great Zimbabwe University produced 37 articles. These constituted 15% of the total articles in the country, and 22% of these articles were produced through international co-authorship. Compared to other fields, the humanities had the least shares of articles produced through international co-authorship.

Table 7.38: Summary profile of the three most research-productive organisations in humanities, 2009–2016

Zimbabwean organisations (sector classification in brackets)	Total number of articles of organisation	As % of total articles in Zimbabwe	As % of total articles in national sector	% articles with international co-authorship
University of Zimbabwe (University sector)	99	41%	49%	38%
Midlands State University (University sector)	59	24%	28%	25%
Great Zimbabwe University (University sector)	37	15%	18%	22%

7.8 Conclusion

This chapter has presented a detailed bibliometric analysis of the research production and collaboration trends of Zimbabwean organisations across four socio-political periods. The data herein analysed was based on an article dataset compiled from Scopus and WoS sources.

It was found that despite having gone through periods of turmoil, Zimbabwe's article output by sector and organisations in each of the six broad fields consistently and significantly increased across the four socio-political periods. Overall, the most productive sectors were the university and the government sector. The NGO sector made significant contributions in the health sciences and social sciences, while international research organisations made strong contributions in the agricultural sciences.

A comparison was made between the summary profile of fields produced by the Scopus and WoS data (i.e. two global databases), and the data set produced with the addition of the NRDZ data (a national database). It was found that, with the exception of the natural sciences and social sciences fields, few, if any, changes were observed when comparing the indicators derived from Scopus and WoS data with the indicators based on all three data sources combined.

The study found that collaboration patterns varied across fields, sectors and organisations. For instance, when only the last period was considered, it was found that in fields such as the health sciences, agricultural sciences and the natural sciences, the most productive sectors, namely the university sector, government sector, local NGO sector and INO sector produced the majority of their articles in collaboration with international co-authors. By contrast, in the humanities, the productive sector (i.e. university sector) produced the bulk of articles without any co-authorship with other Zimbabwean sectors or international authors. However, the collaboration trends of most organisations were more or less similar. It was found that, in general, there was a decrease in the percentage contribution of articles produced through no collaboration/single authorship, and a significant increase in the percentage share of articles produced through international collaboration and through both international and national collaboration.

CHAPTER 8

Bibliometric analysis 3: Participation of 'international national organisations' (INOs) in Zimbabwean research

8.1 Introduction

The study introduces a new measure of international research participation in Africa's research by focusing on international national organisations' (INOs). As mentioned in Chapter 1, bibliometric studies treat international research collaboration as the single most prominent measure of international research participation in the African research landscape, with little attention paid to additional measures tailored for the African context. INOs are one form of international participation in Africa's research. This chapter focuses on the contribution by these organisations to Zimbabwe's research.

As explained in Chapter 5 (see Step 10, Section 5.2.2), the INO sector comprises four different types of organisations:

1. Intergovernmental organisations that operate in Zimbabwe (referred to as 'intergovernmental organisations' in this study);
2. International non-governmental organisations (NGOs), philanthropic organisations, foundations, and think-tanks that operate in Zimbabwe (referred to as 'international NGOs')'
3. International research organisations, research networks, or global research partnerships that operate in Zimbabwe (referred to as 'international research organisations'); and
4. International businesses, companies and firms that operate in Zimbabwe (referred to as 'international industry/businesses').

In the bibliometric analyses presented in Chapters 6 and 7 it became clear that INOs contribute substantially to the country's research production, especially in the fields of the agricultural and health sciences. The chapters illustrated that the percentage contribution of the INO sector to the country's total article output increased over time. For example, the article output of INOs in the health sciences increased steadily from 1% in the first socio-political period, to a contribution of 15% in the last period. Similarly, a systematic increase in article output over time in the agricultural sciences was seen, starting with only 8% in the first period to a high contribution of 36% in the last period.

A detailed analysis of the contribution and participation of the INO sector in Zimbabwe's research is presented in this chapter. The section that follows (Section 8.2) provides an analysis of the INO sector to Zimbabwe's article output.

8.2 Contribution of the INO sector to Zimbabwe's article output

An analysis of Zimbabwean-authored articles in the Scopus and WoS databases, for the period 1980-2016, shows that the total number of articles with at least one INO address was 1 193, which is equivalent to 11% of the country's total article output. Figure 8.1 profiles the annual number of articles produced by the INO sector during the 37-year period. As can be seen, the count of articles increased steadily from 1982, representing a strong correlation (R^2=0.8809) in the annual article output. Although the number of articles produced between 1982 and 2008 fluctuated continuously, there was a significant and constant growth from 2009 onwards.

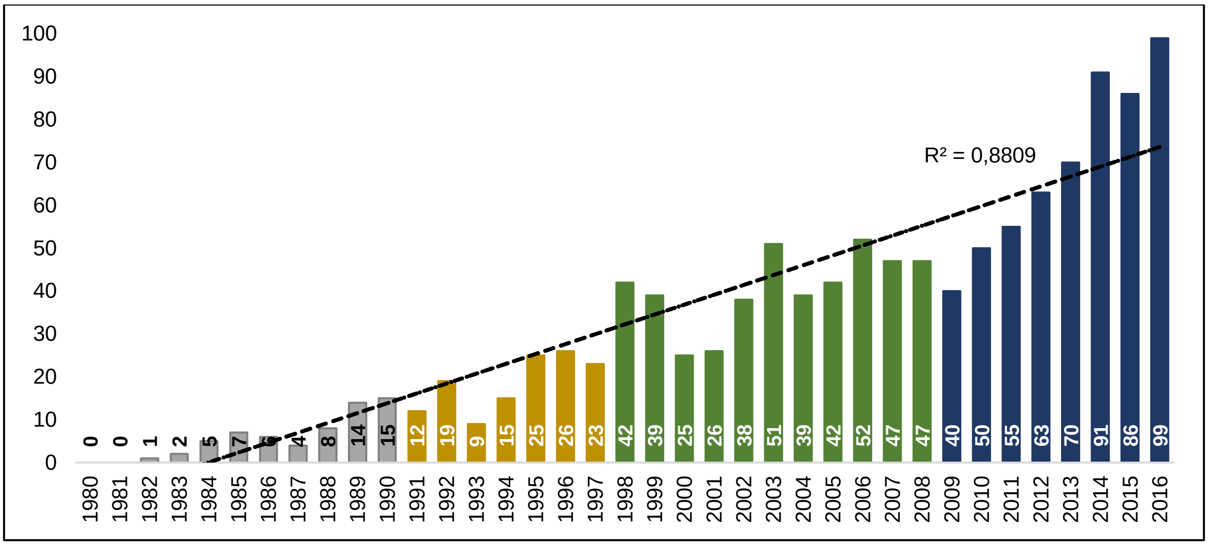

Figure 8.1: Annual number of Scopus and WoS articles produced by the INO sector, 1980-2016

Figure 8.2 shows the annual percentage contribution of the INO sector to the country's total article output for the entire 37-year period. It shows that the contribution by the sector to the country's total article output increased from 1% in 1982 to 15% in 2016. Between 1997 and 1998, the share of articles by the INO sector doubled from 6% to 13%, eventually reaching a peak of 20% in 2006. One possible explanation for the peak could be that research by the national public sector had succumbed to the country's socio-political challenges that prevailed during the period 1998-2007, thereby increasing the reliance on international organisations in Zimbabwe for research.

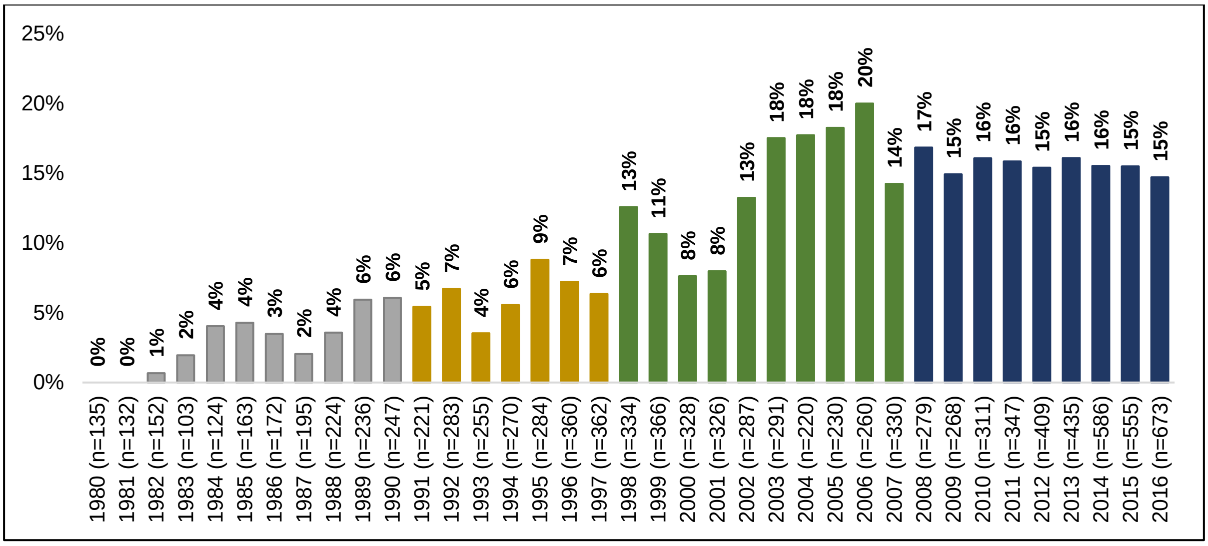

Figure 8.2: Percentage contribution of INOs to Zimbabwe's total annual article output, 1980-2016

8.3 Contribution of the four types of INOs to Zimbabwe's article output

This section profiles Zimbabwe's article output produced by the four different types of INOs. Out of a total of 1 193 articles produced by the INO sector between 1980 and 2016, international research organisations accounted for the largest share, namely 623 (52%) articles, followed by intergovernmental organisations with a total share of 279 (23%). International NGOs followed with a contribution of 276 (23%) and then international industry/businesses, with 42 (4%). Figure 8.3 shows the annual article contribution by these four types of INOs.

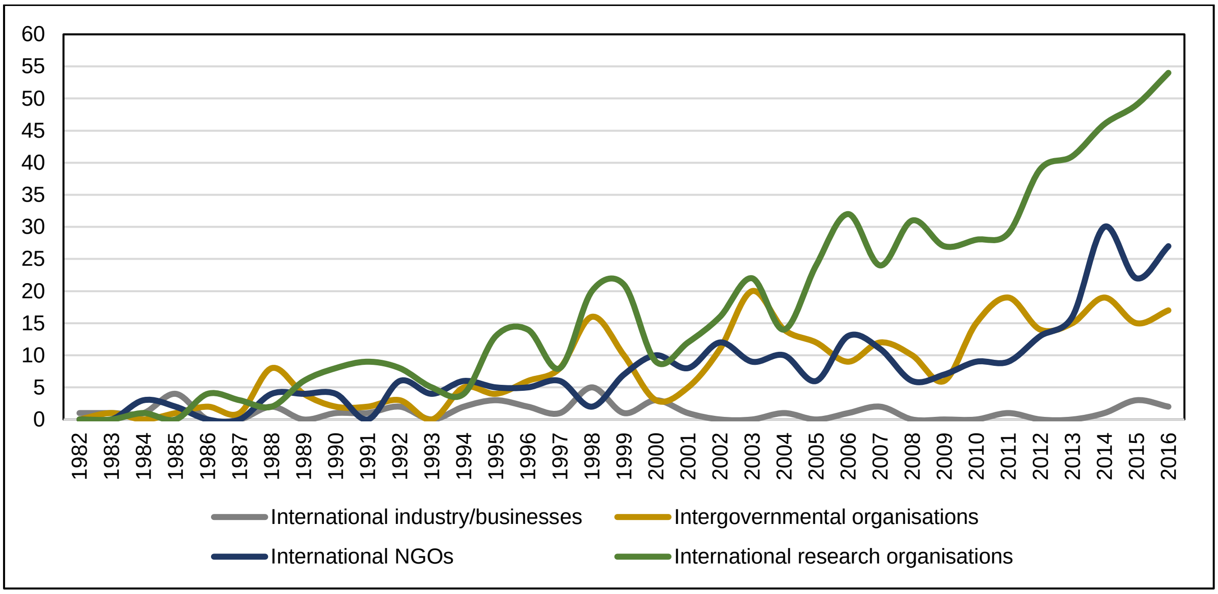

Figure 8.3: Annual number of Scopus and WoS articles produced by four types of INOs, 1980-2016

Figure 8.3 shows that international research organisations were responsible for the largest share of articles by the INO sector, especially between 2004 and 2016. The figure also shows that the annual article output by international industry/businesses remained low across all years. The outputs by intergovernmental organisations and international NGOs seem to fluctuate. This could be the case because unlike international research organisations, which are mainly mandated to carry out research, international NGOs and intergovernmental organisations have several other roles in community and social development. Overall, however, the outputs of these two INO types occupy the middle ground between those of international research organisations and international industry/businesses. The names of the ten INOs with the highest article outputs produced between 1980 and 2016 are provided in Table 8.1.

Table 8. 1: Ten INOs with the largest numbers of article output, 1980-2016

INO details			As share of all Zimbabwean articles (n=10 753)		As share of Zimbabwean articles with INOs (N=1193)	
Name of INO	**Type of INO**	**Head quarters**	**Count**	**%**	**Count**	**%**
International Maize and Wheat Improvement Center (CIMMYT)	International research organisations	Mexico	192	2%	192	16%
World Health Organisation (WHO)	Inter-governmental organisations	Switzerland	173	2%	173	15%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	International research organisations	India	164	2%	164	14%
University of Florida/USAID/SADC Heartwater Research Project	International research organisations	USA	69	1%	69	6%
International Centre for Tropical Agriculture (CIAT)	International research organisations	Colombia	48	<1%	48	4%
Cirad - Zimbabwe	International research organisations	France	44	<1%	44	4%
United Nations Children's Fund (UNICEF)	Intergovernmental organisation	USA	41	<1%	41	3%
Population Services International (PSI)	International NGOs	USA	33	<1%	33	3%
World Agroforestry Centre	International research organisations	Kenya	31	<1%	31	3%
WaterNet - Zimbabwe	International research organisations	Netherlands	30	<1%	30	3%

Table 8.1 shows that the International Maize and Wheat Improvement Center (CIMMYT), with its headquarters in Mexico, was the most frequently counted INO in the country. It produced

16% of the article output by INOs and contributed 2% of the country's total article output. The World Health Organisation (WHO), headquartered in Switzerland, follows with a contribution of 15% of all articles by the INO sector, and 2% of the country's total article output. The table shows that international research organisations were the most prolific type of INO contributing to research in the country. Three out of the ten INOs have their headquarters in the United States (US), which explains why the top collaborating partner of INOs in the study period was the US (see Table 6.5, Chapter 6).

8.4 Single and co-authored articles produced by the INO sector in Zimbabwe

The majority of articles produced by INOs (1 083 or 91%) involved co-authorship, while 110 (9%) were single-authored articles. Figure 8.4 shows the annual breakdown of single and co-authored articles produced by the INOs over the study period. It shows that in any year, co-authorship was the dominant mode of article production for INOs. From 2010 onwards, the production of articles through single authorship was but an exception.

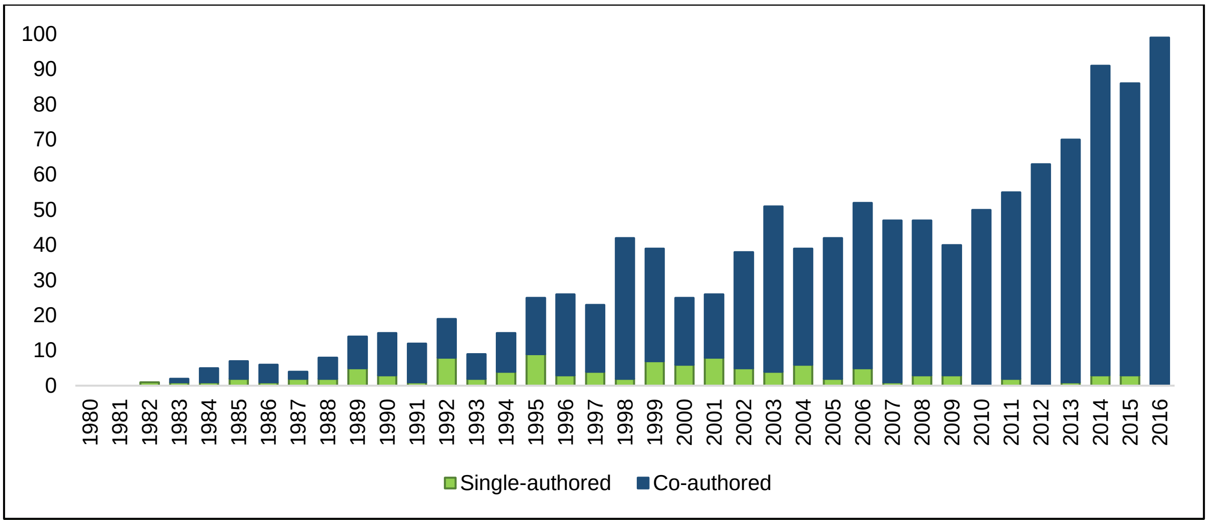

Figure 8. 4: Annual number of single and co-authored articles produced by INOs, 1980-2016

According to Figure 8.4, the highest count of single-authored articles was recorded in 1995. A list of INOs contributing to single-authored articles in that year is provided in Table 8.2 below. It is noted in the table that five of the nine single-authored articles were produced by international research organisations with headquarters in France, India and the US. Two international NGOs were responsible for the remaining four single-authored articles in 1995.

Table 8.2: Single-authored articles produced by INOs in 1995

Name of INO	Headquarters	Type of INO	Number of single articles produced in 1995
Oxfam – Zimbabwe	Kenya	International NGOs	3
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	India	International research organisations	2
Cirad – Zimbabwe	France	International research organisations	1
Practical Action	United Kingdom	International NGOs	1
United Nations Children's Fund (UNICEF),	USA	International research organisations	1
University of Florida/USAID/SADC Heartwater Research Project	USA	International research organisations	1

The study found that of all the co-authored articles (1 083) produced by the INO sector during the period under review, 527 (49%) involved international collaboration only. Moreover, 368 (34%) were generated through both international and national collaboration, while the remaining 188 (17%) involved national collaboration only. Considering that the majority (49%) of articles produced by INOs involved international collaboration only, one might ask whether this specific subset of articles reflect ‘true’ Zimbabwean articles, especially since INOs are another form of international participation. The same question can be asked of INO articles that are single authored.

8.5 Contribution of INOs to Zimbabwe’s article output in six broad fields

In this section, the contribution of Zimbabwean INOs to the article output in six broad fields is considered. Out of a total of 1 193 articles produced by the INO sector between 1980 and 2016, the largest share of articles with an INO address, 457 (38%), was in the agricultural sciences. A further 400 (34%) were in the health sciences and 371 (31%) in the natural sciences, while 33 (3%) and 19 (2%) were in the fields of engineering and technologies and the humanities, respectively. Figure 8.5 shows the broad field breakdown of all Zimbabwean articles involving INOs.

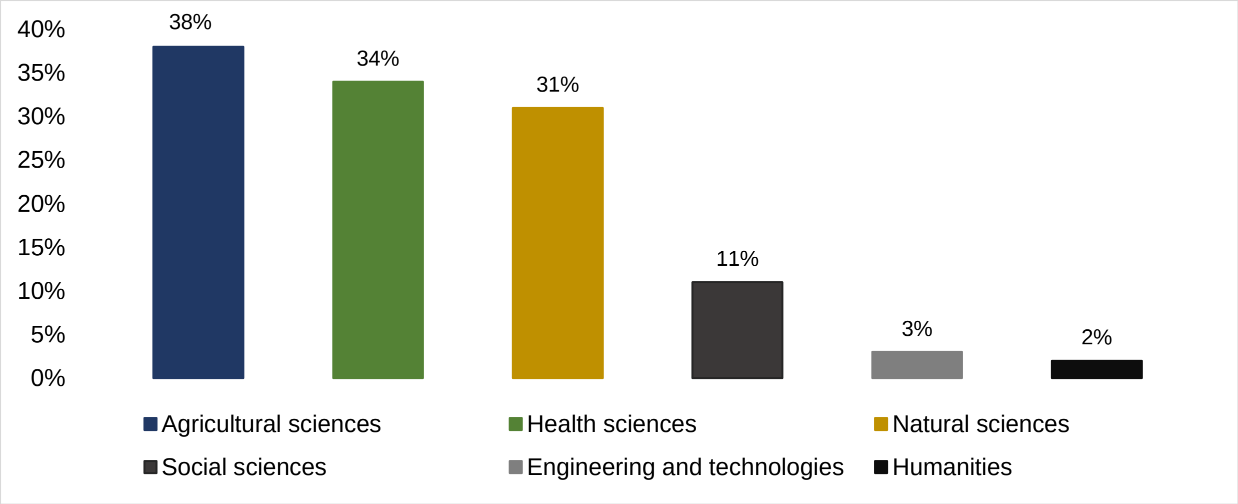

Figure 8.5: Percentage distribution of articles involving INOs by broad field, 1980-2016

Figure 8.6 shows the annual output of the INO sector by field. The figure shows that the annual number of articles produced by the INO sector in the six fields increased over time. For example, the number of articles with an INO address in the natural sciences increased from two articles in 1983 to 31 articles in 2016. In health sciences, articles with an INO address increased from three articles in 1985 to a high of 44 articles in 2016. Although the contribution in agricultural sciences also increased, a major drop by the sector between 1998 and 2000 (from 20 to eight articles) can be seen. Another significant decline in agricultural sciences is seen between 2002 and 2004 (from 22 to six articles). Possible reasons for these decreases could be the completion of a major project or an INO moving into a different field or area of work. Given the very low numbers of outputs in both engineering and technologies and the humanities, it appears that INOs have not played much of a role in these two fields at any point over the period. In the other three fields, however, INOs had a relatively greater presence in terms of article output since the 1990s. Further significant increases in the article output by INOs in these three fields are associated with the last socio-political period, which started in 2009.

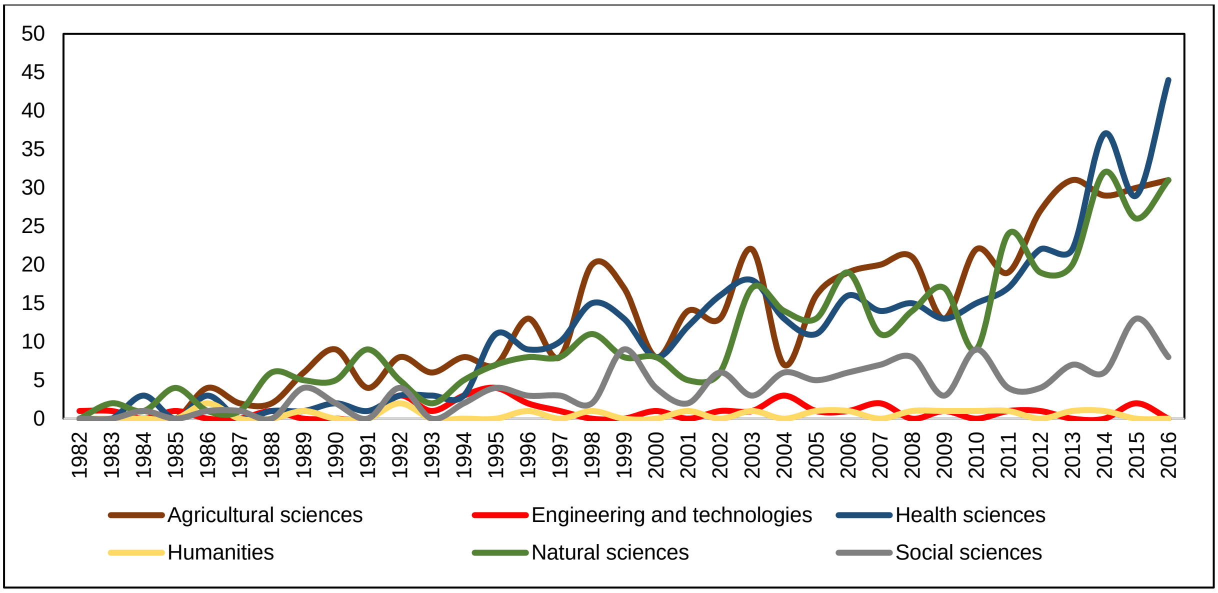

Figure 8.6: Annual number of articles produced by INOs in Zimbabwe, by broad field, 1980-2016

A detailed analysis of the participation of INOs in each of the six broad fields was also undertaken. For these, a new classification framework of authorship types was developed that combines the phenomenon of INOs with the different kinds of authorship; namely, single versus co-authored articles, and nationally versus internationally co-authored articles. Essentially, the framework aimed to consider the phenomenon of INOs as one form of international participation, together with international co-authorship as another form of international participation. The framework development is discussed next.

8.6 Developing a classification framework to study the contribution of INOs to article output in the six broad fields

A relevant framework to shed light on the link between INOs and the different kinds of authorship was developed by creating and cross-tabulating four variables in the database of Scopus and WoS articles. The following variables were created:

- Number of article authors (coded as ‘1’ and ‘≥2’);
- Number of international countries authoring the article (coded as ‘0’ and ‘≥1’);
- Number of national organisations authoring the article (coded as ‘1’ and ‘≥2’); and
- Type of national organisation, which could be either be an INO or the opposite of an INO, a so-called ‘true’ national organisation (TNO).

The first two variables (i.e. number of article authors and number of international countries authoring the article) were created by determining the number of authors per article, and by establishing whether an article listed at least one other country – apart from Zimbabwe – in the author address. The number of international countries per article reflected unique country names. The third and fourth variables (i.e. number of national organisations authoring the article and the type of national organisation, INO or TNO) were created from a non-duplicate list of standardised names of Zimbabwean author organisations. The names of the organisations were sorted into 13 sectors (see Chapter 5, Step 10), where after each organisation was classified as either an INO or TNO.

Table 8.3 illustrates the eight national sectors that were classified as TNOs (first column) and the four sectors that constitute INOs (second column).

Table 8.3: Classification of Zimbabwean sectors and the alignment with TNOs and INOs

Eight sectors involving TNOs	Four sectors involving INOs
Zimbabwean university (e.g. National University of Science and Technology)	Intergovernmental organisation (e.g. Food and Agriculture Organization – Zimbabwe)
Zimbabwean national and local government (e.g. Department of Veterinary Services, Tsetse and Trypanosomiasis Control Branch)	International research organisation/network or global or regional research partnership that operates in Zimbabwe (e.g. International Crops Research Institute for the Semi- Arid Tropics)
Zimbabwean NGO/community based organisation/faith based organisation (e.g. Iluba Elimnyama Theatre Works)	International NGO/philanthropic organisation/foundation/think-tank that operates in Zimbabwe (e.g. Elizabeth Glaser Pediatric AIDS Foundation)
Zimbabwean industry/business/company/firm (e.g. National Foods Limited)	International business/company/firm that operates in Zimbabwe (e.g. Deloitte and Touche Zimbabwe)
Zimbabwean private school/college/university (e.g. Christian Brothers College)	Note: There is also a 13th sector, called 'other', which includes, for instance, unknown street and postal addresses.
Zimbabwean private clinic/hospital (e.g. Royal Women's Clinic)	
Zimbabwean mission/faith-based hospital (e.g. Sanyati Baptist Hospital)	
Zimbabwean union/association (e.g. Zimbabwe Psychological Association)	

Cross-tabulation of the four variables resulted in a framework that comprises 20 authorship types. Table 8.4 shows the classification framework and clarifies how the authorship types were derived.

Table 8.4: Classification framework of 20 types of authorship

Number of article authors	Number of national organisations	Number of international countries: 0	Number of international countries: ≥1
1	1	Single-authored articles • Type 1: TNO only • Type 2: INO only	Single-authored articles • Type 6: TNO only • Type 7: INO only
1	≥2	Single-authored articles • Type 3: TNO only • Type 4: INO only • Type 5: TNO & INO	Single-authored articles • Type 8: TNO only • Type 9: INO only • Type 10: TNO & INO
≥2	1	Nationally co-authored articles • Type 11: TNO only • Type 12: INO only	Internationally co-authored articles • Type 16: TNO only • Type 17: INO only
≥2	≥2	Nationally co-authored articles • Type 13: TNO only • Type 14: INO only • Type 15: TNO & INO	Internationally co-authored articles • Type 18: TNO only • Type 19: INO only • Type 20: TNO & INO

Based on the information provided in Table 8.4, two examples are highlighted by way of illustration. Type 1 represents a single-authored article, produced by a single Zimbabwean organisation without any international co-authorship, and where the organisation belongs to any of the eight sectors in the first column of Table 8.3. Type 10, on the other hand, represents a single-authored article produced by an author with more than one affiliation. One of the addresses of the author belongs to an organisation in Zimbabwe while the other belongs to an organisation outside of Zimbabwe.

The field-specific profiles of INOs, which include data for the classification framework of authorship types, are presented in the following sections. The broad fields are discussed in order from the highest to the lowest contributions by INO sector (refer to Figure 8.5 above). The fields of engineering and technologies, and the humanities, relative to the other four fields, recorded the fewest contributions by the INO sector; as such, there are not reported on.

8.7 Participation of INOs in the agricultural sciences in Zimbabwe

Articles in the agricultural sciences accounted for 38% of all Zimbabwean articles with an INO address affiliation, the highest share for any of the six fields. Applying the classification framework of authorship types to these agricultural articles (Table 8.5), it was found that three types of authorships dominated in the first period. Two of these were Type 1 (34%), which represents a single TNO involving one author, and Type 11 (28%), which also represents a single TNO but with more than one author. What this means is that in the first period, agricultural articles were produced through single authorship (Type 1) and through intra-institutional collaboration (Type 11). However, the contribution by both these types decreased significantly over time, recording minimal shares of 2% and <1%, respectively, in the last period. Type 16, which indicates co-authorship between a TNO and partners from one or more international countries, also had a marked presence in the first period and maintained its presence in all four periods, reaching its peak (37%) in the third period. Types 13 and 16 dominated the last period, with percentage contributions of 23% and 22%, respectively. When only authorship types involving INOs are considered, Type 17, which indicates co-authorship between a single INO and one or more international countries, was found to be the highest contributor by INOs, producing 15% and 14 % of articles in period 3 and 4, respectively. This indicates that the majority of articles produced by INOs in agricultural sciences were generated through international co-authorship. One obvious explanation for this pattern is that INOs rely on international networks for funding on research.

Table 8.5: Types of authorship in agricultural sciences, by socio-political period

Types	Socio-political periods							
	1980–1990		1991–1997		1998–2008		2009–2016	
	Count	%	Count	%	Count	%	Count	%
Type 1 (aa=1; no=1; ic=0; TNO only)	106	34%	62	14%	37	5%	9	2%
Type 2 (aa=1; no=1; ic=0; INO only)	5	2%	11	2%	4	1%	1	<1%
Type 3 (aa=1; no=≥2; ic=0; TNO only)	0	0%	1	<1%	1	<1%	0	0%
Type 4 (aa=1; no=≥2; ic=0; INO only)	0	0%	0	0%	0	0%	0	0%
Type 5 (aa=1; no=≥2; ic=0; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 6 (aa=1; no=1; ic=≥1; TNO only)	2	1%	4	1%	3	<1%	2	<1%
Type 7 (aa=1; no=1; ic=≥1; INO only)	1	<1%	0	0%	1	<1%	1	<1%
Type 8 (aa=1; no=≥2; ic=≥1; TNO only)	0	0%	0	0%	0	0%	0	0%
Type 9 (aa=1; no=≥2; ic=≥1; INO only)	0	0%	0	0%	0	0%	0	0%
Type 10 (aa=1; no=≥2; ic=≥1; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 11 (aa=≥2; no=1; ic=0; TNO only)	88	28%	142	32%	75	10%	2	<1%
Type 12 (aa=≥2; no=1; ic=0; INO only)	6	2%	14	3%	4	1%	1	0%
Type 13 (aa=≥2; no=≥2; ic=0; TNO only)	19	6%	32	7%	93	12%	123	22%
Type 14 (aa=≥2; no=≥2; ic=0; INO only)	0	0%	2	<1%	2	<1%	17	3%
Type 15 (aa=≥2; no=≥2; ic=0; TNO&INO)	4	1%	2	<1%	12	2%	24	4%
Type 16 (aa=≥2; no=1; ic=≥1; TNO only)	60	19%	119	26%	284	37%	130	23%
Type 17 (aa=≥2; no=1; ic=≥1; INO only)	7	2%	21	5%	125	16%	76	14%
Type 18 (aa=≥2; no=≥2; ic=≥1; TNO only)	9	3%	35	8%	102	13%	92	16%
Type 19 (aa=≥2; no=≥2; ic=≥1; INO only)_	0	0%	1	<1%	11	1%	42	8%
Type 20 (aa= ≥2; no=≥2; ic=≥1; TNO&INO)	2	1%	4	1%	18	2%	40	7%
Total	**309**	**100%**	**450**	**100%**	**772**	**100%**	**560**	**100%**

Notes:
aa=number of article authors; no=number of national organisations; ic=number of international countries; TNO=true national organisation; INO=international national organisation.
All percentages of 10% and above are highlighted to show concentrations of authorship types.

Figure 8.7 shows the total percentage contributions of INOs to agricultural sciences in the four socio-political periods. The figure shows that participation by INOs in the field increased consistently since period one. Out of a total of 309 articles produced in the first period, 8% were accounted for by the INO sector. In the last period, the INO sector accounted for more than a quarter (36%) of the total 560 agricultural articles produced during that period.

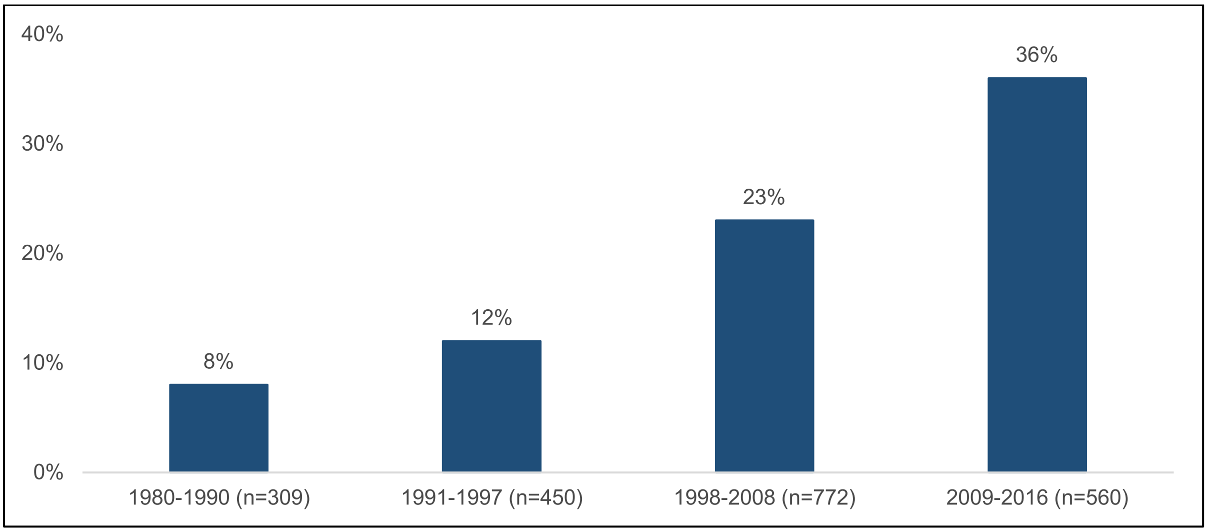

Figure 8.7: Percentage contributions of INOs to agricultural sciences in Zimbabwe, by socio-political period

The five INOs in the agricultural sciences responsible for the largest article output appear in Table 8.6 below. The table shows that the International Maize and Wheat Improvement Center (CIMMYT) consistently produced articles throughought the period under review. The International Centre for Tropical Agriculture (CIAT) and Cirad, did not produce articles in the second and third periods. This could mean either that research projects between the respective organisations and Zimbabwe could have come to an end, or the organisations were engaging in developmental programmes that did not result in publications. A full list of the INOs involved in the agricultural sciences in the country between 1980 and 2016 is provided as Appendix 13.

Table 8.6: Five INOs with the largest numbers of article output in agricultural sciences, by socio-political period

Name of INO (type of INO in brackets)	1980-1990 (n=24)		1991-1997 (n=54)		1998-2008 (n=177)		2009-2016 (n=202)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
International Maize and Wheat Improvement Center (CIMMYT) (International research organisations)	3	13%	7	13%	44	25%	112	55%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (International research organisations)	7	29%	10	19%	39	22%	53	26%
International Centre for Tropical Agriculture (CIAT) (International research organisations)	10	42%	--	--	--	--	26	13%
Cirad – Zimbabwe (International research organisations)	2	8%	--	--	--	--	10	5%
Seed Co – Zimbabwe (International industry/businesses)	1	4%	--	--	4	2%	5	2%

Note: Percentages exceed 100% because some articles involve co-authorship between different INOs

The collaboration patterns of the CIMMYT in Zimbabwe are shown in Figure 8.8. The period covered in the figure is 1998-2016 because prior to those years, CIMMYT produced only a few articles. Out of a total of 44 articles produced by CIMMYT between 1998 and 2008, the majority of these (77%) involved international collaboration only, while 16% were produced through both international and national collaboration. The collaboration pattern changed in the last period as national collaboration became more visible. The majority of articles (43%) produced in the last period involved both international and national collaboration, while 39% were produced through international collaboration only. These results show that, with time, CIMMYT was collaborating more with local researchers which means it could have established more local networks.

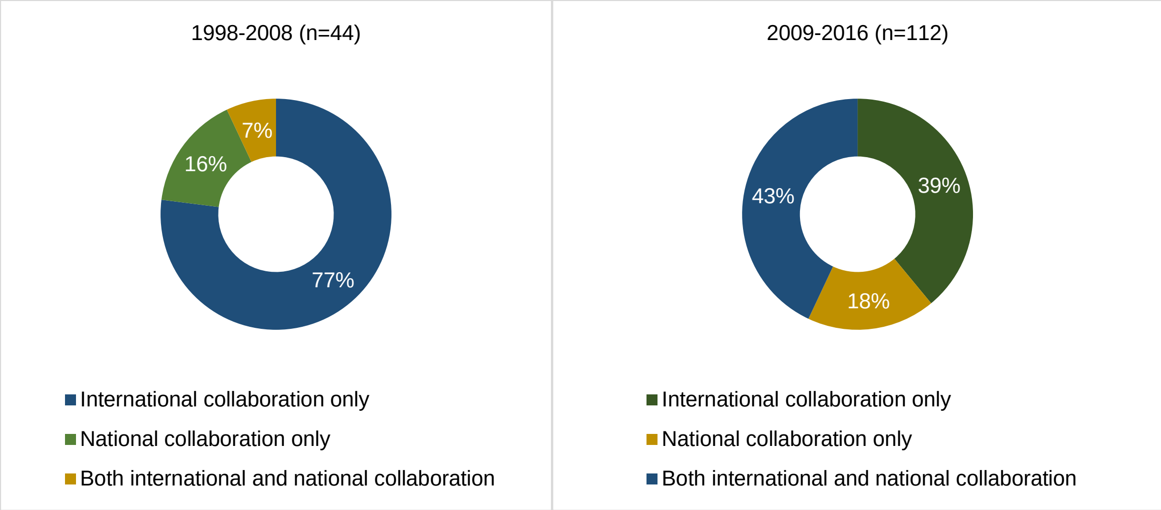

Figure 8.8: Articles in agricultural sciences by the International Maize and Wheat Improvement Center (CIMMYT), broken down by national and international collaboration – a comparison of two periods

Figure 8.9 shows an analysis of the intersection of the two kinds of international participation – international collaboration and participation of INOs – in the agricultural sciences in the four socio-political periods. For the purpose of the analysis, all agricultural articles with international and INO addresses were categorised into three mutually exclusive groups:

1. International co-authorship only
2. INO only
3. Both international co-authorship and INO.

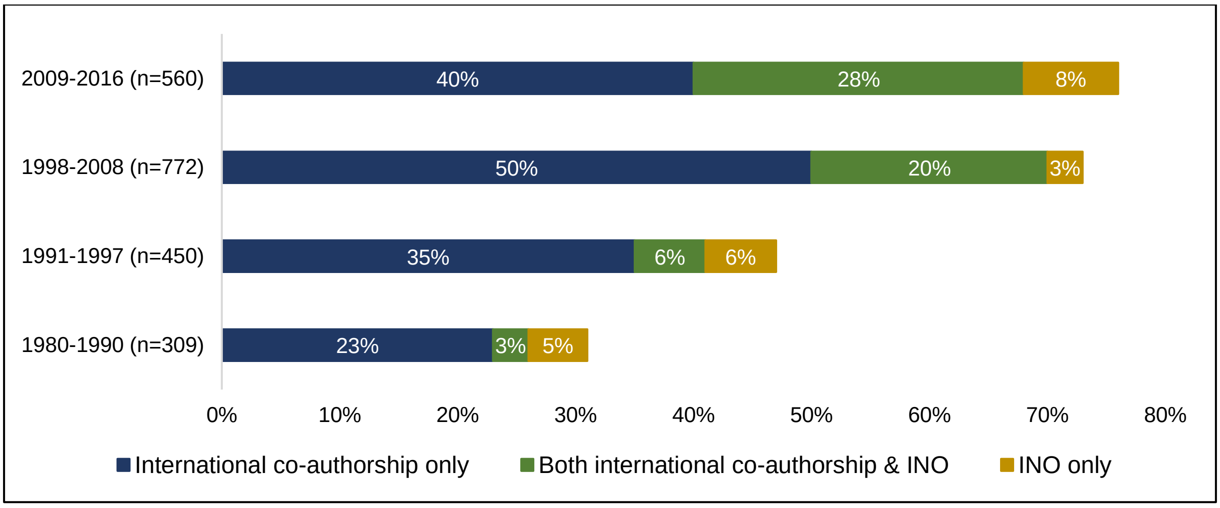

Figure 8.9: Percentage breakdown of two kinds of international participation in agricultural sciences in Zimbabwe, by socio-political period

Note: The percentages for each period in the figure do not add up to 100% because the focus was only on international co-authorship and INOs. Single-authored articles and articles with only national co-authorship have been excluded.

Figure 8.9 shows that there was an increase in the percentage of articles produced through international co-authorship, and in the percentage of articles produced through both international co-authorship and INOs. It is evident in the figure that participation by INOs without international co-authorship also being simultaneously present was minimal. For instance, between 1991 and 1997, out of a total of 450 agricultural articles produced during that period, 41% involved international co-authorship, of which 6% also included INOs. Only 6% of articles were produced by INOs only. In the next period (2009-2016), 68% of the articles produced involved international co-authorship, of which 28% also listed participation by an INO, while 8% were generated by INOs only.

The results in this section indicate that INOs had a marked presence in Zimbabwe's agricultural research. The organisations produced most of their articles in co-authorship with international partners. The next section focuses of INOs in the field of the health sciences.

8.8 Participation of INOs in the health sciences in Zimbabwe

Articles in the health sciences accounted for 34% of all Zimbabwean articles with an INO address affiliation, the second highest share for any of the six fields. Applying the classification framework of authorship types to these agricultural articles (Table 8.7), it was found that four types of authorship dominated the first and second periods. These were Type 1, Type 11, Type 13 and Type 16. Authorship Type 16 (26%), which indicates co-authorship between a TNO and partners from one or more international countries, dominated the second period. This type of authorship had a marked presence in all four periods. Type 13, which represents nationally co-authored articles, also had a consistent presence throughout the study period, reaching a peak of 21% in the second period. The last period was largely dominated by authorship Type 18 (37%), which indicates co-authorship between TNOs and international partners. These results demonstrate that there was a significant increase in articles produced by authors collaborating with international partners and a decrease in articles produced by single authors. This could reflect the reality that, as already mentioned in Chapter 6, foreign funding from the UK and the US in fields such as health and agriculture usually involves research partnerships between countries from both Africa and elsewhere. When only authorship types involving INOs were considered, Type 17, which indicates co-authorship between a single INO and one or more international countries, was found to be the highest contributor by INOs, producing 8% and 7% of articles in the third and last periods, respectively. The latter indicates that INOs in health sciences collaborate more with researchers from outside Zimbabwe as compared to collaborating with local researchers. The reason for this preference could be to gain access to research funds and equipment.

Table 8.7: Types of authorship in health sciences, by socio-political period

Types	Socio-political periods							
	1980–1990		1991–1997		1998–2008		2009–2016	
	Count	%	Count	%	Count	%	Count	%
Type 1 (aa=1; no=1; ic=0; TNO only)	335	36%	128	14%	87	7%	23	2%
Type 2 (aa=1; no=1; ic=0; INO only)	0	0%	7	1%	8	1%	0	0%
Type 3 (aa=1; no=≥2; ic=0; TNO only)	1	<1%	0	0%	0	0%	5	0%
Type 4 (aa=1; no=≥2; ic=0; INO only)	0	0%	0	0%	0	0%	0	0%
Type 5 (aa=1; no=≥2; ic=0; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 6 (aa=1; no=1; ic=≥1; TNO only)	4	0%	4	<1%	10	1%	8	1%
Type 7 (aa=1; no=1; ic=≥1; INO only)	0	0%	0	0%	1	<1%	1	<1%
Type 8 (aa=1; no=≥2; ic=≥1; TNO only)	0	0%	0	0%	1	<1%	0	0%
Type 9 (aa=1; no=≥2; ic=≥1; INO only)	0	0%	0	0%	0	0%	0	0%
Type 10 (aa=1; no=≥2; ic=≥1; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 11 (aa=≥2; no=1; ic=0; TNO only)	367	39%	226	25%	69	6%	1	<1%
Type 12 (aa=≥2; no=1; ic=0; INO only)	2	<1%	1	<1%	3	<1%	0	0%
Type 13 (aa=≥2; no=≥2; ic=0; TNO only)	106	11%	186	21%	216	18%	151	12%
Type 14 (aa=≥2; no=≥2; ic=0; INO only)	0	0%	1	0%	1	<1%	2	<1%
Type 15 (aa=≥2; no=≥2; ic=0; TNO&INO)	2	<1%	6	1%	9	1%	10	1%
Type 16 (aa=≥2; no=1; ic=≥1; TNO only)	92	10%	237	26%	414	34%	425	33%
Type 17 (aa=≥2; no=1; ic=≥1; INO only)	5	1%	24	3%	100	8%	85	7%
Type 18 (aa=≥2; no=≥2; ic=≥1; TNO only)	21	2%	76	8%	283	23%	475	37%
Type 19 (aa=≥2; no=≥2; ic=≥1; INO only)_	0	0%	2	<1%	5	<1%	17	1%
Type 20 (aa= ≥2; no=≥2; ic=≥1; TNO&INO)	1	<1%	0	0%	25	2%	84	7%
Total	**936**	**100%**	**898**	**100%**	**1232**	**100%**	**1287**	**100%**

Notes:
aa=number of article authors; no=number of national organisations; ic=number of international countries; TNO=true national organisation; INO=international national organisation.
All percentages of 10% and above are highlighted to show concentrations of authorship types.

Figure 8.10 shows the total percentage contributions of INOs to the health sciences in the four socio-political periods. The figure shows that participation by INOs in the field increased consistently over time. For example, the percentage contribution by the sector increased from 1% in the first period to 15% in the last period.

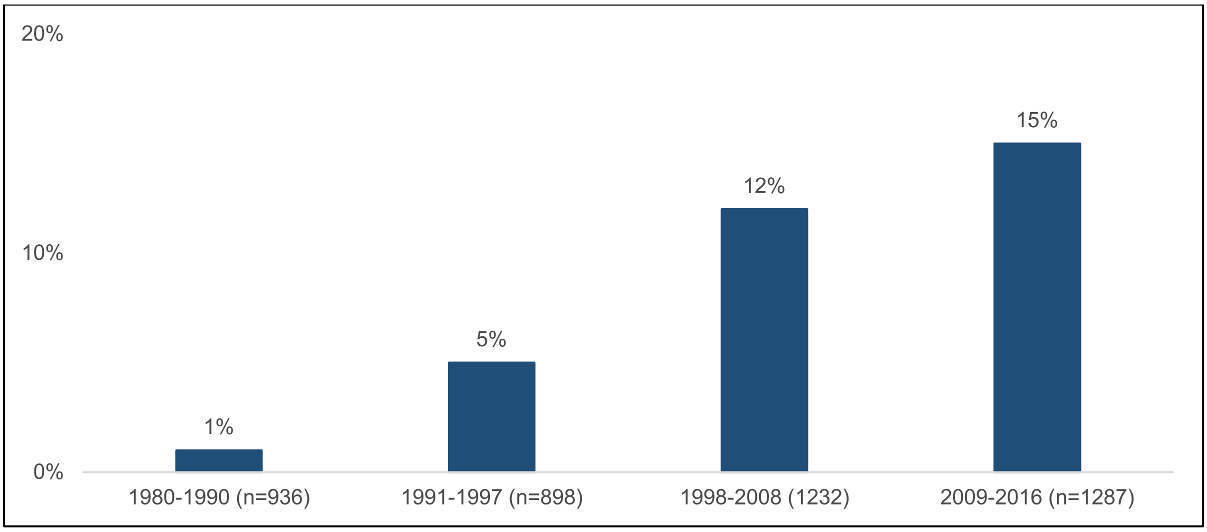

Figure 8.10: Percentage contributions of INOs to health sciences in Zimbabwe, by socio-political period

The five INOs in the health sciences with the largest article output are shown in Table 8.8. Table 8.8 illustrates that the World Health Organisation (WHO) was the major contributor of health science articles. The WHO accounted for 64 (32%) of health sciences articles produced by the INO sector in the last period. It was followed by Population Services International with a percentage share of 11%. Together, these two organisations accounted for 43% of the 199 articles produced by the INO sector in the last period, provided there is little or no shared co-authorship between these two organisations. A full list of the INOs producing health science articles in the country between 1980 and 2016 is provided in Appendix 14.

Table 8.8: Five INOs with the largest numbers of article output in health sciences, by socio-political period

Name of INO (type of INO in brackets)	1980-1990 (n=10)		1991-1997 (n=40)		1998-2008 (n=151)		2009-2016 (n=199)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
World Health Organisation (WHO) (Intergovernmental organisations)	--	--	11	26%	81	54%	64	32%
Population Services International (PSI) (International NGOs)	--	--	--	--	--	--	21	11%
United Nations Children's Fund (UNICEF) (Intergovernmental organisations)	--	--	3	7%	6	4%	16	8%
Centers for Disease Control and Prevention (International research organisations)	--	--	--	--	9	6%	12	6%
Cirad – Zimbabwe (International research organisations)	--	--	--	--	--	--	12	6%

The collaboration patterns of the WHO are highlighted in Figure 8.11. The figure shows that the majority of articles produced by the WHO involved international collaboration only. For example, out of a total of 81 articles produced between 1998 and 2016, 78% involved international collaboration only. The figure also shows that 96% of the articles produced between 2009 and 2016 had some form of international participation (i.e. 69% produced through international collaboration only, while 27% involved both international and national collaboration). Based on the results provided in Figure 8.11, it is seen that majority of articles produced by the WHO involved international co-authorship.

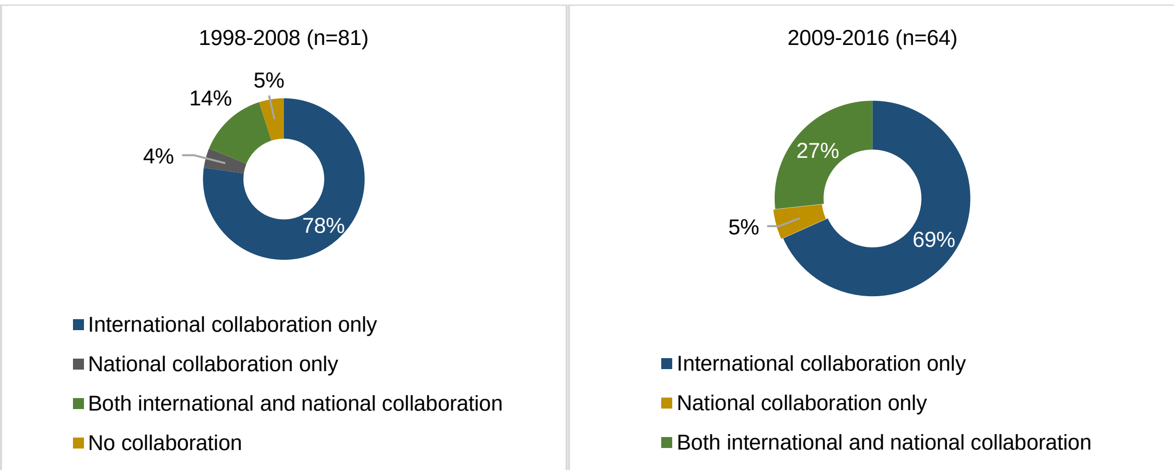

Figure 8.11: Articles in health sciences by the World Health Organisation (WHO), broken down by national and international collaboration – a comparison of two periods

A breakdown of the different the two kinds of international participation (INOs and international co-authorship) in health sciences, by socio-political period, is provided in Figure 8.12. All health science articles with international and INO addresses were categorised into three mutually exclusive groups:

1. International co-authorship only
2. INO only
3. Both international co-authorship and INO.

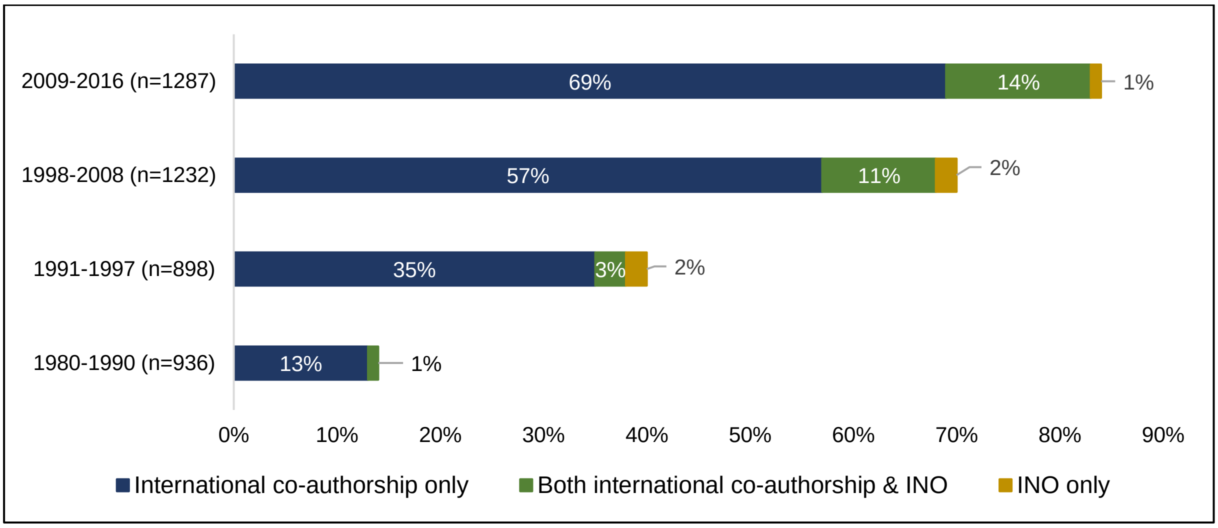

Figure 8.12: Percentage breakdown of two kinds of international participation in health sciences in Zimbabwe, by socio-political period

Figure 8.12 shows that there was a significant increase in the share of articles in the health sciences produced through international co-authorship only. The relevant share increased from 13% in the first period to 69% in the last period. The figure further shows that participation by INOs, without the presence of international co-authorship, was an exception rather than the norm. For instance, out of a total of 1 232 health science articles produced in the period 1998-2008, 68% involved international co-authorship, of which 11% listed participation by an INO. In the following period (2009-2016), out of a total of 1 287 articles produced during that period, 73% involved international co-authors, of which 14% listed an INO address. These results thus show that in the health sciences, the participation of INOs co-occur with international co-authorship; specifically, INO participation seldom occurs without international co-authorship whereas international co-authorship occurs without INO participation.

8.9 Participation of INOs in the natural sciences in Zimbabwe

Articles in natural sciences accounted for 371 (31%) of all Zimbabwean articles with an INO address affiliation. A breakdown of the 20 different authorship types through which natural science articles in Zimbabwe were produced, by socio-political period, is shown in Table 8.9. The table shows that in the first period, articles in the natural sciences were mainly produced by a single Zimbabwe TNO involving one author, as indicated by authorship Type 1 (44%). This was followed by authorship Type 11 (22%), which involves a single TNO and more than one author, and authorship Type 16 (20%), which represents a single TNO in collaboration involving co-authorship by more than one international country. The table shows that percentage contributions by authorship Type 1 decreased from 44% in the first period to 6% in the last period, while percentage shares by authorship Type 16 increased from 20% in the first period to a high percentage of 42% in the third period, dropping slightly to 35% in the last period. Type 17, which indicates co-authorship between a single INO and one or more international countries, was found to be the highest contributor by INOs, producing 1% and 3% of articles in period one and two respectively and 5% in period three and four.

Table 8.9: Types of authorship in natural sciences, by socio-political period

Types	Socio-political periods							
	1980–1990		1991–1997		1998–2008		2009–2016	
	Count	%	Count	%	Count	%	Count	%
Type 1 (aa=1; no=1; ic=0; TNO only)	214	44%	133	22%	147	13%	70	6%
Type 2 (aa=1; no=1; ic=0; INO only)	6	1%	14	2%	9	1%	5	<1%
Type 3 (aa=1; no=≥2; ic=0; TNO only)	0	0%	0	0%	3	<1%	2	<1%
Type 4 (aa=1; no=≥2; ic=0; INO only)	0	0%	0	0%	0	0%	0	0%
Type 5 (aa=1; no=≥2; ic=0; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 6 (aa=1; no=1; ic=≥1; TNO only)	5	1%	9	1%	18	2%	12	1%
Type 7 (aa=1; no=1; ic=≥1; INO only)	0	0%	0	0%	2	<1%	0	0%
Type 8 (aa=1; no=≥2; ic=≥1; TNO only)	0	0%	0	0%	0	0%	1	<1%
Type 9 (aa=1; no=≥2; ic=≥1; INO only)	0	0%	0	0%	0	0%	0	0%
Type 10 (aa=1; no=≥2; ic=≥1; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 11 (aa=≥2; no=1; ic=0; TNO only)	105	22%	159	26%	96	9%	2	<1%
Type 12 (aa=≥2; no=1; ic=0; INO only)	8	2%	9	1%	7	1%	1	<1%
Type 13 (aa=≥2; no=≥2; ic=0; TNO only)	25	5%	38	6%	124	11%	271	22%
Type 14 (aa=≥2; no=≥2; ic=0; INO only)	1	<1%	3	<1%	2	<1%	8	1%
Type 15 (aa=≥2; no=≥2; ic=0; TNO&INO)	2	<1%	4	1%	12	1%	14	1%
Type 16 (aa=≥2; no=1; ic=≥1; TNO only)	96	20%	185	30%	468	42%	408	33%
Type 17 (aa=≥2; no=1; ic=≥1; INO only)	6	1%	19	3%	60	5%	63	5%
Type 18 (aa=≥2; no=≥2; ic=≥1; TNO only)	14	3%	31	5%	134	12%	288	23%
Type 19 (aa=≥2; no=≥2; ic=≥1; INO only)_	2	<1%	3	<1%	7	1%	22	2%
Type 20 (aa= ≥2; no=≥2; ic=≥1; TNO&INO)	3	1%	3	<1%	28	3%	65	5%
Total	**487**	**100%**	**610**	**100%**	**1117**	**100%**	**1232**	**100%**

Notes:
aa=number of article authors; no=number of national organisations; ic=number of international countries; TNO=true national organisation; INO=international national organisation.
All percentages of 10% and above are highlighted to show concentrations of authorship types.

When all authorship types with INOs were combined (Figure 8.13), it was found that the share of articles produced by the sector increased from 5% in the first period to 14% in the last period. Moreover, out of a total of 487 natural sciences articles produced in the first period, 5% had at least one INO address. The INO sector accounted for 14% of the total (1 232) articles produced in the last period.

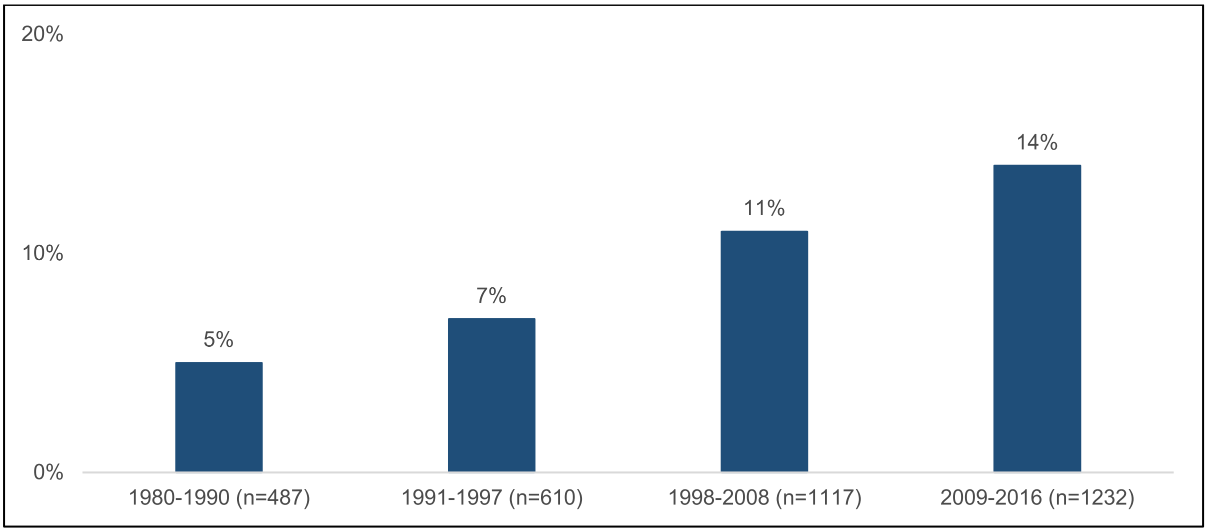

Figure 8.13: Percentage contributions of INOs to natural sciences in Zimbabwe, by socio-political period

A list of five INOs in natural sciences with the largest article output is provided in Table 8.10. Only the top-producing organisations in the last period were selected. The table illustrates that with a contribution of 21%, the CIMMYT produced the highest share of natural sciences articles in the last period, followed by the ICRISAT at 17%. A close analysis of these results shows that the CIMMYT produces articles in agricultural, health and natural sciences. This could be an issue of multiple subject classification of journals in which CIMMYT publishes in.

Table 8.10: Five INOs with the largest numbers of article output in natural sciences, by socio-political period

Name of INO (type of INO in brackets)	1980-1990 (n=25)		1991-1997 (n=42)		1998-2008 (n=126)		2009-2016 (n=178)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
International Maize and Wheat Improvement Center (CIMMYT) (International research organisations)	--	--	--	--	6	5%	38	21%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (International research organisations)	4	16%	3	7%	26	21%	30	17%
Cirad – Zimbabwe (International research organisations)	--	--	3	7%	2	2%	18	10%
World Health Organisation (WHO) (Intergovernmental organisations)	--	--	4	10%	17	13%	17	10%
Population Services International (PSI) (International NGO)	--	--	--	--	--	--	12	7%

Figure 8.14 shows the collaborative profile of ICRISAT for the period 1998-2016. The figure shows that the majority of articles were produced through international collaboration – either alone or together with national collaboration. For example, of the 30 articles produced between 2009 and 2016, 47% involved international collaboration only, while 43% were generated through both international and national collaboration.

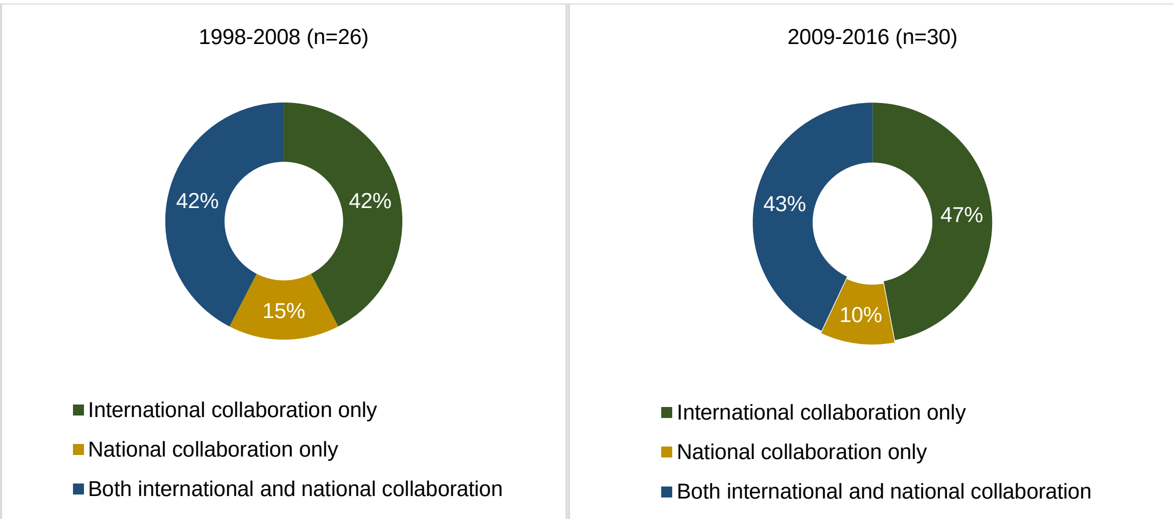

Figure 8.14: Articles in natural sciences by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), broken down by national and international collaboration – a comparison of two periods

Figure 8.15 indicates that international co-authorship played an important role in the production of natural sciences articles in the INO sector. The underlying analysis is based on data that capture the overlap between the contribution by INOs and international co-authorships in the natural sciences, using three mutually exclusive categories:

1. International co-authorship only
2. INO only
3. Both international co-authorship and INO.

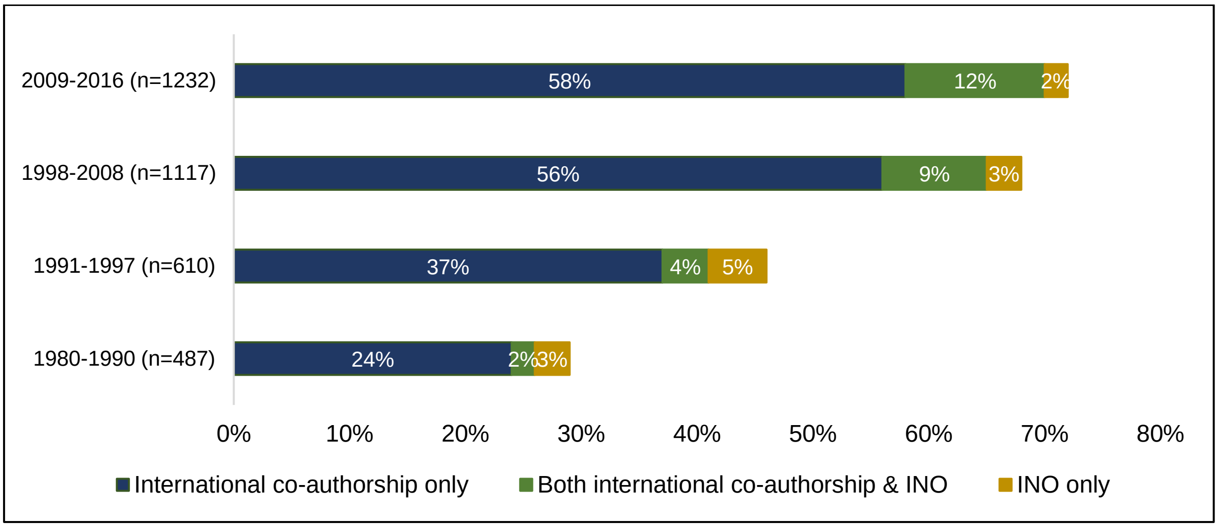

Figure 8.15: Percentage breakdown of two kinds of international participation in natural sciences in Zimbabwe, by socio-political period

Figure 8.15 shows that there was an increase in the percentage of articles produced through international co-authorship, and in the percentage of articles produced through both international co-authorship and INOs. The figure shows that participation by INOs without international co-authorship also being simultaneously present was minimal, especially during the third and fourth periods. For instance, between 2009 and 2016, out of a total of 1 232 natural sciences articles, 70% involved international co-authorship, of which 9% also included INOs. Only 3% of articles were produced by INOs only.

8.10 Participation of INOs in the social sciences in Zimbabwe

Applying the classification framework of authorship types to social sciences articles in Zimbabwe (Table 8.11) revealed that the participation of INOs in the field is insignificant. None of the authorship types involving INOs seems to feature in the relevant table. Articles were mainly produced through authorship Type 1 (single-authored articles involving a TNO only), with shares of 64% and 44% in the first and second periods, respectively. Although the corresponding shares for Type 1 in the third and fourth periods dropped to 27% and 20%, the contribution remained significant. The contribution by Type 16, which represents a single Zimbabwean TNO together with authors from one or more international countries, increased over time from 7% in the first period to a dominant status of 32% in the last period. Type 11 (single Zimbabwean TNO involving more than one author) and Type 18 (two or more TNOs involving one or more international countries) exhibit different trends. Whereas Type 11 had a strong presence in the first and second periods, diminishing thereafter, Type 18 became most prominent in the last two periods. It is important to note that unlike in the agricultural, health and natural sciences, in the social sciences, Type 1 had strong contributions throughout the study period. One can conclude from this that the types of authorship in Zimbabwe are field-specific.

Table 8.11: Types of authorship in social sciences, by socio-political period

Types	Socio-political periods							
	1980–1990		1991–1997		1998–2008		2009–2016	
	Count	%	Count	%	Count	%	Count	%
Type 1 (aa=1; no=1; ic=0; TNO only)	150	65%	124	44%	109	27%	145	20%
Type 2 (aa=1; no=1; ic=0; INO only)	4	2%	10	4%	20	5%	1	<1%
Type 3 (aa=1; no=≥2; ic=0; TNO only)	0	0%	0	0%	0	0%	1	<1%
Type 4 (aa=1; no=≥2; ic=0; INO only)	0	0%	0	0%	0	0%	0	0%
Type 5 (aa=1; no=≥2; ic=0; TNO&INO)	0	0%	0	0%	2	<1%	0	0%
Type 6 (aa=1; no=1; ic=≥1; TNO only)	8	3%	4	1%	8	2%	23	3%
Type 7 (aa=1; no=1; ic=≥1; INO only)	1	<1%	0	0%	1	<1%	1	<1%
Type 8 (aa=1; no=≥2; ic=≥1; TNO only)	0	0%	0	0%	0	0%	5	1%
Type 9 (aa=1; no=≥2; ic=≥1; INO only)	0	0%	0	0%	0	0%	0	0%
Type 10 (aa=1; no=≥2; ic=≥1; TNO&INO)	0	0%	0	0%	0	0%	0	0%
Type 11 (aa=≥2; no=1; ic=0; TNO only)	34	15%	48	17%	9	2%	4	1%
Type 12 (aa=≥2; no=1; ic=0; INO only)	1	<1%	0	0%	2	<1%	0	0%
Type 13 (aa=≥2; no=≥2; ic=0; TNO only)	13	6%	17	6%	29	7%	130	18%
Type 14 (aa=≥2; no=≥2; ic=0; INO only)	0	0%	0	0%	3	1%	5	1%
Type 15 (aa=≥2; no=≥2; ic=0; TNO&INO)	1	<1%	1	<1%	4	1%	5	1%
Type 16 (aa=≥2; no=1; ic=≥1; TNO only)	16	7%	61	22%	148	37%	229	32%
Type 17 (aa=≥2; no=1; ic=≥1; INO only)	2	1%	4	1%	22	5%	18	3%
Type 18 (aa=≥2; no=≥2; ic=≥1; TNO only)	2	1%	11	4%	43	11%	120	17%
Type 19 (aa=≥2; no=≥2; ic=≥1; INO only)_	0	0%	1	<1%	1	<1%	8	1%
Type 20 (aa= ≥2; no=≥2; ic=≥1; TNO&INO)	0	0%	0	0%	3	1%	16	2%
Total	**232**	**100%**	**281**	**100%**	**404**	**100%**	**711**	**100%**

Notes:
aa=number of article authors; no=number of national organisations; ic=number of international countries; TNO=true national organisation; INO=international national organisation.
All percentages of 10% and above are highlighted to show concentrations of authorship types.

The total contributions of INOs in the social sciences in the four socio-political periods are presented in Figure 8.16. It is observed in the figure that the contribution by INOs in the social sciences peaked in the third period, during which INOs accounted for 14% of the total 404 articles produced in the field. However, the contribution by the sector dropped to 8% in the last period. An examination of the article counts for INOs in the social sciences in the last two periods show that the average number of social sciences articles with an INO address increased from five articles per year to seven articles per year in the last period. This means that the INO sector managed to sustain its production. The subsequent decrease in the percentage share of the INO sector, from 14% to 8% (Figure 8.16), could be the because of other sectors producing more articles over that period.

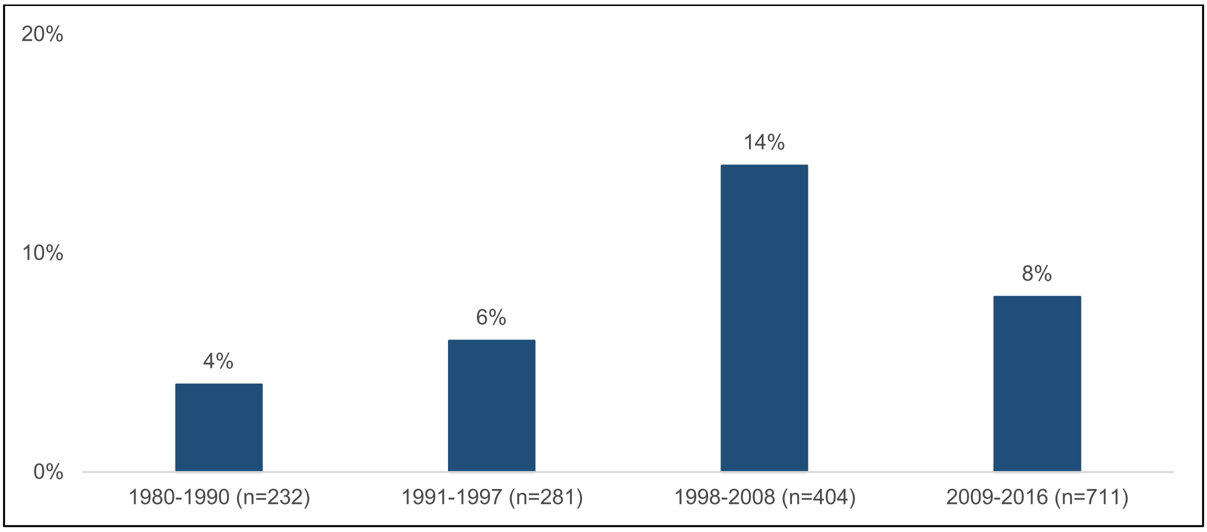

Figure 8.16: Percentage contributions of INOs to social sciences in Zimbabwe, by socio-political period

Table 8.12 shows the five INOs responsible for the largest number of articles in the social sciences. The table shows that United Nations Children's Fund (UNICEF) was the largest producer of social sciences articles in the last period, accounting for 19% of all articles produced by the INO sector. The International Maize and Wheat Improvement Center (CIMMYT) followed with a percentage contribution of 17%. The presence of CIMMYT in social sciences, as mentioned in Section 8.9, could be an issue of multiple subject classification of journals in which CIMMYT publishes in.

Table 8.12: Five INOs with the largest numbers of article output in social sciences, by socio-political period

Name of INO (type of INO in brackets)	1980-1990 (n=9)		1991-1997 (n=16)		1998-2008 (n=58)		2009-2016 (n=54)	
	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles	Number of articles	% articles
United Nations Children's Fund (UNICEF) (Intergovernmental organisations)	1	11%	--	--	4	7%	10	19%
International Maize and Wheat Improvement Center (CIMMYT) (International research organisations)	--	--	--	--	5	9%	9	17%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (International research organisations)	--	--	--	--	7	12%	7	13%
International Centre for Tropical Agriculture (CIAT) (International research organisations)	--	--	--	--	2	2%	6	11%
Population Services International (PSI) (International NGOs)	--	--	--	--	4	7%	3	6%

A percentage breakdown of the two kinds of international participation in the social sciences in Zimbabwe, by socio-political period, is provided in Figure 8.17. International participation refers to either one or both forms of international participation, as indicated by three mutually exclusive categories:

1. International co-authorship only
2. INO only
3. Both international co-authorship and INO.

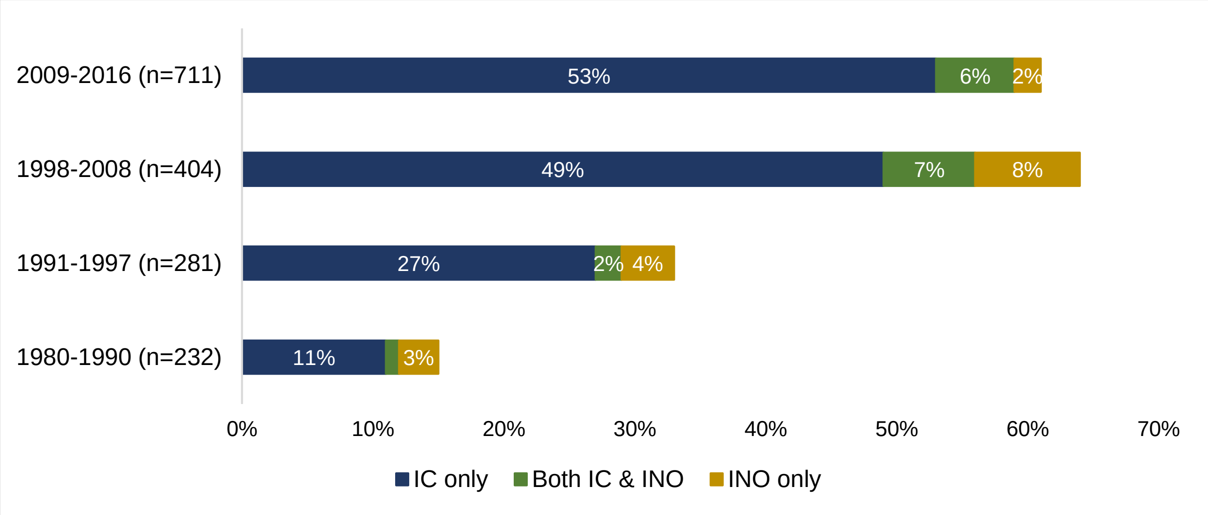

Figure 8.17: Percentage breakdown of two kinds of international participation in social sciences in Zimbabwe, by socio-political period

It is evident in Figure 8.17 that the percentage of articles produced through international co-authorship in the social sciences grew from 11% in the first period to 53% in the last. In addition, the percentage of articles produced by INOs only grew from 3% in the first period to 8% in the third, decreasing to 2% in the last period. The figure shows that in the last period, the majority of articles produced by INOs involved international co-authorship. For instance, out of 711 articles produced in that period, 59% involved international authors, of which 6% were produced by both international authors and INOs, and 2% were produced by INOs only.

8.12 Conclusion

This chapter has shown that the percentage contribution of the INO sector to Zimbabwe's total article output increased over time, from 1% in 1982 to 15% in 2016. In 2006, the sector contributed about 20% to the country's total article output. One explanation provided for this peak was that since research by the national public sector had succumbed to the country's socio-political challenges that prevailed during the period 1998-2007, there was increased reliance on international organisations in Zimbabwe for research.

International research organisations accounted for the largest share of articles, followed by intergovernmental organisations, international NGOs and, lastly, international industry/businesses. The CIMMYT, an international research organisation with headquarters in Mexico, was the most frequently counted INO in the country. The WHO, an intergovernmental organisation (headquartered in Switzerland) followed in second place.

Overall, international research organisations were the most prolific type of INO contributing to research in the country.

The largest share of articles with an INO address were in the agricultural sciences, followed by those in the health sciences, natural sciences, and social sciences (in that order). Engineering and technologies, and the humanities, recorded the fewest contributions by the INO sector. When applying the classification framework of authorship types to the six broad fields, it was generally found that two types of authorship dominated the first and second periods. These were Type 1 which represents a single TNO involving one author, and Type 11 which also represents a single TNO but with more than one author. What this means is that, in the first period, articles were produced mainly through single authorship (Type 1) and through intra-institutional collaboration (Type 11). The contribution by both these types decreased significantly over time. Type 16, which indicates co-authorship between a TNO and partners from one or more international countries, had a consistent presence in all four periods, in all the fields except engineering and the humanities. When only authorship types involving INOs were considered, Type 17, which indicates co-authorship between a single INO and one or more international countries, was found to be the highest contributor for articles involving INOs. This indicates that the majority of articles produced by INOs were generated through international co-authorship. One obvious explanation for this pattern is that INOs rely on international networks for funding on research.

The analysis of the intersection of the two kinds of international participation in the respective fields, in the four socio-political periods, showed that there was an increase in the percentage of articles produced through international co-authorship, and in the percentage of articles produced through both international co-authorship and INOs. It was found that participation by INOs without international co-authorship also being simultaneously present was minimal. Overall, INOs have a marked presence in Zimbabwe's agricultural, health and natural sciences research. The INOs produced most of their articles in co-authorship with international partners.

CHAPTER 9

Bibliometric analysis 4: Author-level analyses of Zimbabwean researchers

9.1 Introduction

The previous result chapters presented bibliometric analyses of research output and research collaboration in Zimbabwe based on article-level data. In other words, the analyses originated from a dataset where articles represented the cases or units of analysis, with a table of authorships and a table of field classifications used to generate relevant output based on the article-level data. This chapter provides the results of a series of author-level bibliometric analyses of the Zimbabwean research workforce responsible for articles published between 2009 and 2016. These analyses are derived from a dataset for which the article authors (and not the articles) are the cases or units of analysis.

Most bibliometric studies on African science tend to use articles as the main unit of analysis. This is despite the fact that individual researchers, and not the articles they produce, are the sources of research production and collaboration. In this regard, this study sought to determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets as opposed to author-level datasets are analysed.

As discussed in Chapter 5 (Step 12 in Section 5.2.2), the article dataset was converted into a dataset of article authors by using the authorship table as an intermediary step in the conversion process. Having both article- and author-level data allowed, among others, for a comparison between the shares of *articles* with collaboration, and the shares of article *authors* involved in collaboration. Presented first is a profile of the authors responsible for Zimbabwe's article output in the period under review (Section 9.2). This is followed by a presentation of the modes of collaboration of the Zimbabwean authors based on a comparative analysis of an article-level and author-level dataset (Section 9.3). Finally, in Section 9.4, the publication outputs of Zimbabwean authors with dual national-international affiliation are presented.

9.2 Profile of authors responsible for Zimbabwe's article output

A total of 11 606 authors were identified as having been responsible for 3 584 Zimbabwean articles produced between 2009 and 2016. Of this total, 2 896 were classified as reporting Zimbabwean addresses (authors with at least one Zimbabwean address for any article produced during the period under review), and 8 710 as reporting international addresses only (authors with only an international address for any article produced during the period under review). The two groups respectively indicate Zimbabwean authors and international authors. Of the 2 896 Zimbabwean authors, 400 (14%) also reported an international address together with a Zimbabwean address as their author address in one of their articles (dual national-international affiliation). Analysis of the field and sector classification of the Zimbabwean research workforce is presented in the sections that follow.

9.2.1 Profile of Zimbabwean authors in six broad fields

Figure 9.1 shows the overall profile of Zimbabwean authors in six broad fields. As can be seen, between 2009 and 2016, a plurality (42%) of the 2 896 Zimbabwean authors were classified as based in the natural sciences. The second largest concentration of authors during the period under review was in the health sciences (41%), followed by authors in the social sciences (28%).

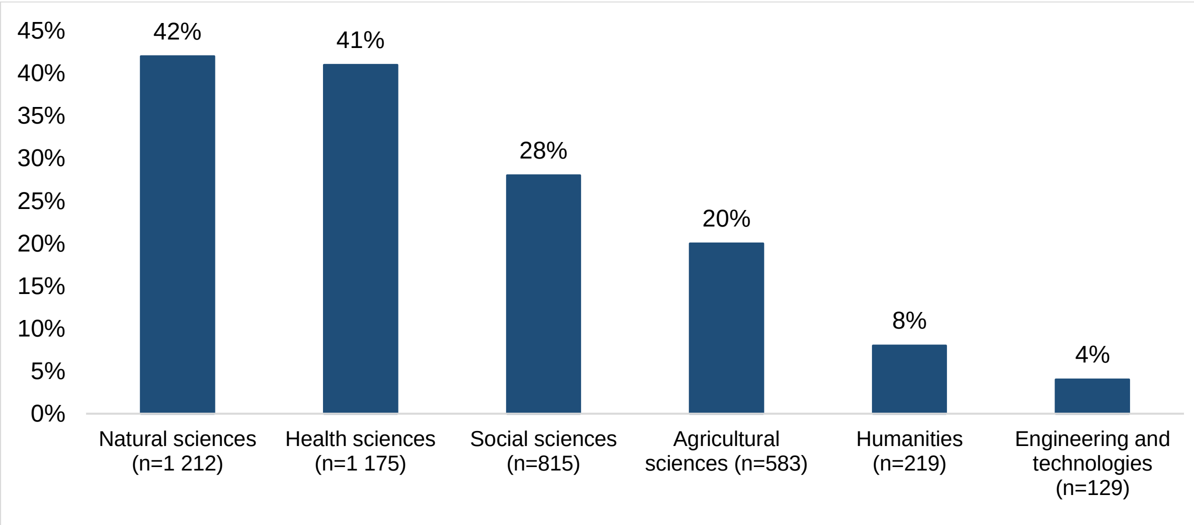

Figure 9.1: Distribution of Zimbabwean authors by broad field, 2009-2016

It is important to note that the sum of percentages presented in Figure 9.1 exceed 100%, primarily because the field categories of article authors were not mutually exclusive, meaning an author could produce articles in more than one field. For this reason, an analysis of the extent of overlap of authors in the different fields was undertaken, as shown in Table 9.1.

Table 9.1 shows that out of a total of 129 authors publishing in engineering and technologies, 64% of the same authors also published in the natural sciences. Out of a total of 583 authors publishing in the agricultural sciences, 29% also published in the natural sciences. Similarly, 25% of the 219 authors in the humanities had also published in the social sciences. Two explanations can be offered for these overlaps. One is that authors published in journals with dual classifications. For example, the *Biochemical Engineering Journal* is classified in two fields (engineering and technologies, and the natural sciences) and the *Journal of Bio-resource Technology* is classified in both the agricultural and natural sciences. Another explanation for the overlap could be that authors produced several articles in different journals, where the journals are classified in different fields.

Table 9.1: Extent of overlap of Zimbabwean authors in six broad fields, 2009-2016

	NS (n=1212)	**HS (n=1175)**	**SS (n=815)**	**AS (n=583)**	**HU (n=219)**	**ET (n=129)**
NS	--	22%	8%	29%	3%	64%
HS	21%	--	14%	11%	1%	2%
SS	6%	10%	--	2%	25%	0%
AS	14%	6%	1%	--	1%	6%
HU	<1%	<1%	7%	<1%	--	0%
ET	7%	<1%	0	1%	0%	--

Note: NS=natural sciences, HS=health sciences, SS=social sciences, AS=agricultural sciences, HU=humanities, ET=engineering and technologies

Figure 9.2 presents, for each of the six broad fields, a comparative analysis of the annual number of articles vis-à-vis the annual number of authors producing those articles. It is important to note that, for any field in Figure 9.2, the sum of the number of authors in each year will be different from the total number of authors reported for that field in Figure 9.1. This is because an author could be counted more than once in any of the fields in Figure 9.2, simply because the same author can publish articles in different years.

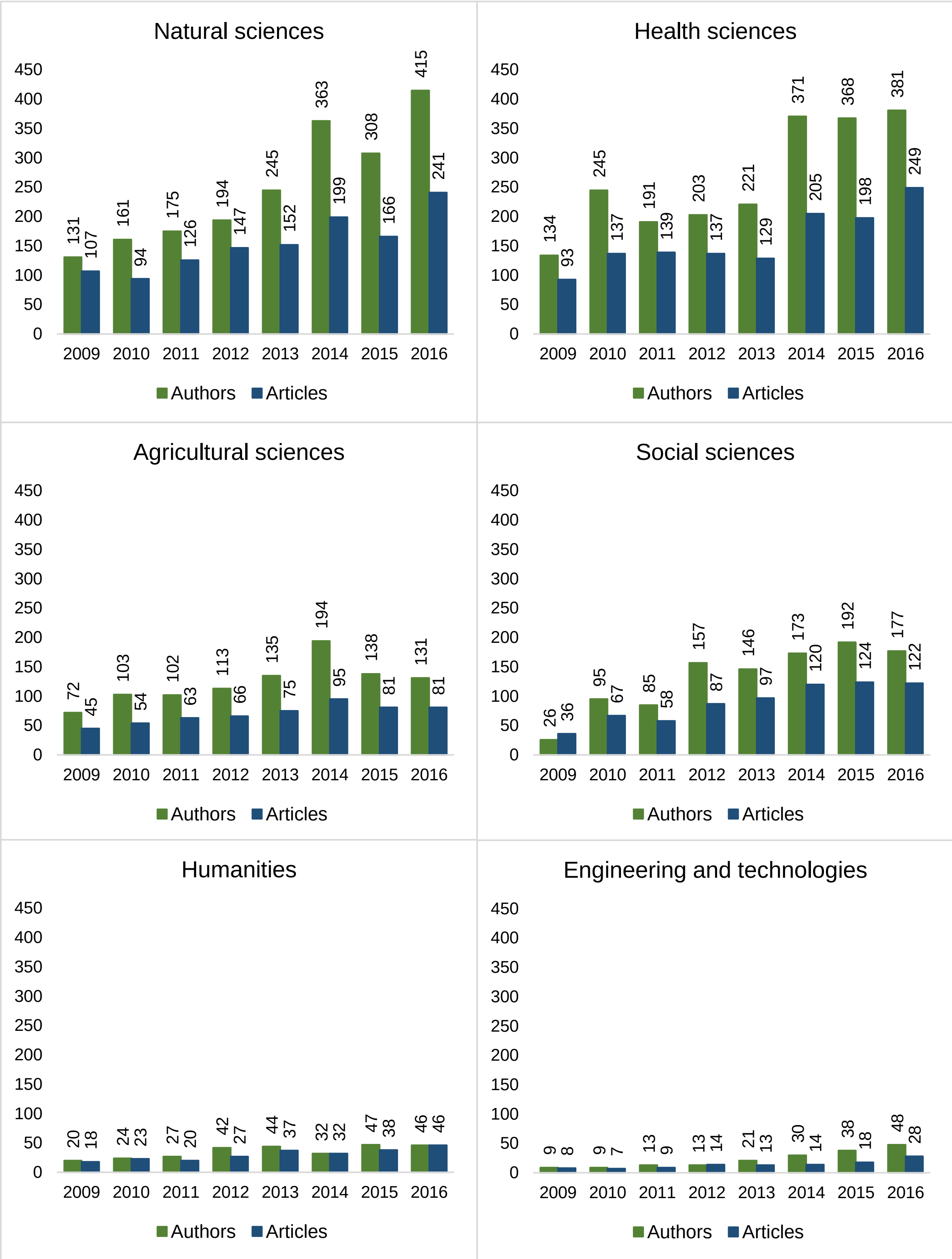

Figure 9.2: Comparative analysis of the annual number of articles vis-à-vis the annual number of Zimbabwean authors that produced the articles, by year and broad field, 2009-2016

Figure 9.2 shows that, apart from the field of humanities, in any given year, the number of Zimbabwean authors is more than the number of articles produced. The fields of natural and health sciences display similar trends in terms of the size and growth of authors vis-à-vis the size and growth of articles. The humanities and the engineering and technology fields have the lowest number and growth of articles, as well as the lowest number and growth of authors producing those articles. The agricultural sciences also show a different trend as compared to other fields. While other fields showed an upward trend in the number of authors producing articles during the period under review, there was a downward trend in the agricultural sciences. For instance, the annual number of Zimbabwean authors producing articles in the field decreased from 194 in 2014 to 131 in 2016. The number of articles produced in the field also dropped from 95 in 2014 to a constant 81 articles per year in 2015 and 2016.

Based on the number of Zimbabwean authors producing articles in a year (in Figure 9.2), average numbers of articles by those authors in each broad field were calculated (see Figure 9.3). It is important to note that the ratios in Figure 9.3 are less than 1 because the figures are based on the unique numbers of articles in a specific year and the unique authors in that same year. For instance, if three individual researchers co-authored the same two articles, this simply means there were three authors and two articles. The average article per author is calculated by dividing the two articles by three authors, with the result of an average of 0,67 articles per author.

A value less than 1 indicates that there were more authors than articles. For instance, Figure 9.2 shows a general trend in the natural sciences where, in any given year, the number of authors surpassed the number of articles. Hence, the average number of articles by an author in the field (shown in Figure 9.3) is less than 1. In contrast, the average number of articles produced by authors in the humanities is high because articles are produced by fewer authors. For instance, Figure 9.2 shows that in 2014, 32 authors in the humanities were responsible for 32 articles, which translates to an average of 1.0 article per author, as shown in Figure 9.3.

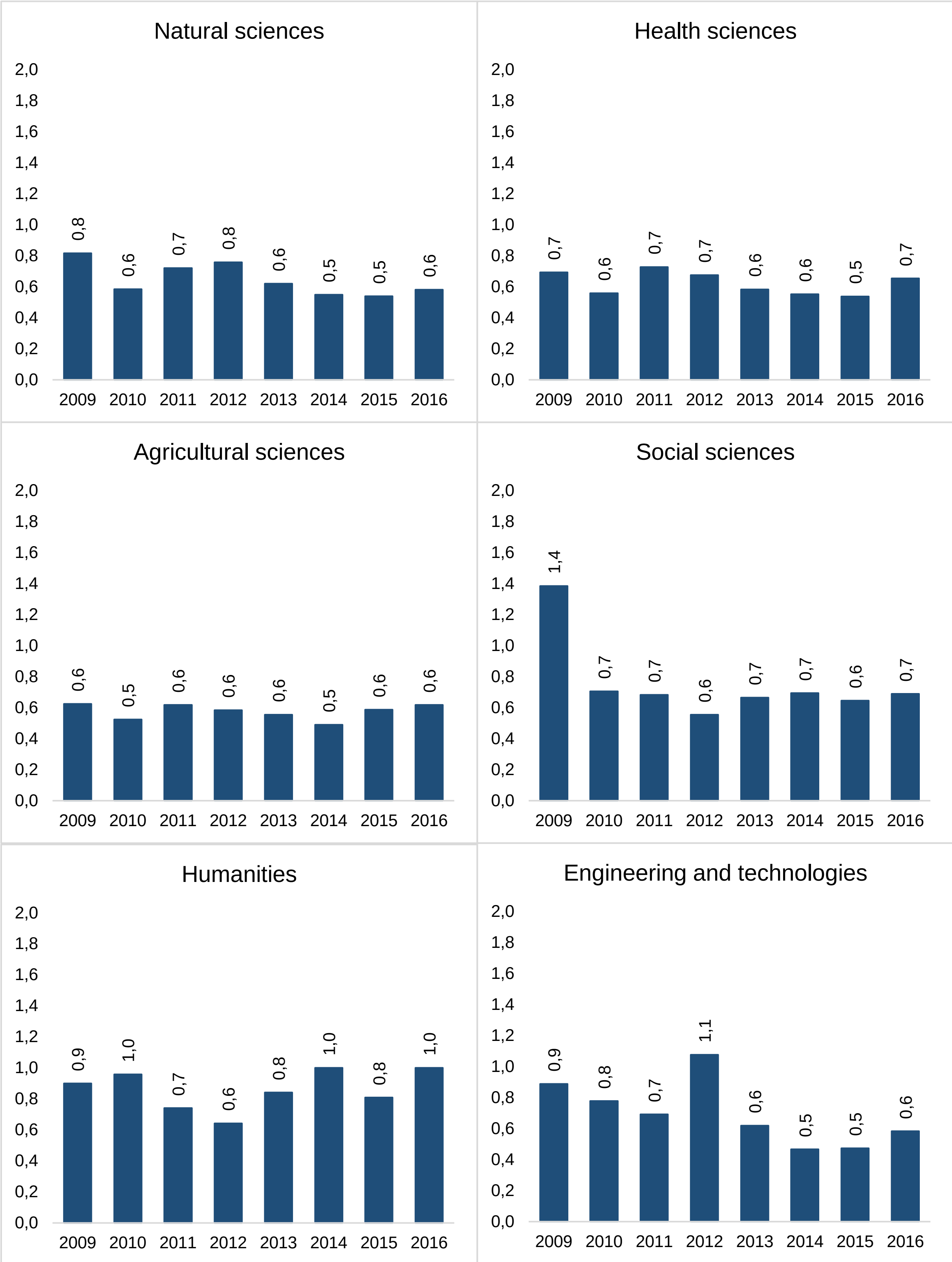

Figure 9.3: Average number of articles per Zimbabwean author, by year and broad field

Having profiled the number of Zimbabwean authors responsible for the production of articles in each broad field during the period 2009-2012, the focus now shifts to all the authors, including international co-authors, responsible for the article output in each field, over the same period. Based on their address affiliations, authors were classified into three mutually exclusive categories:

- Zimbabwean only
- International only
- Both Zimbabwean and international.

Figure 9.4 shows the distribution of address affiliations of all article authors in each broad field. The figure shows that with the exception of humanities, in any given year the highest number of authors responsible for article production in Zimbabwe had an international affiliation. For example, in 2016, out of a total of 2 684 authors responsible for articles in the health sciences, the majority (86%) had an international affiliation, while 12% had a Zimbabwean address only, and only 2% had both a Zimbabwean and international address. This indicates that Zimbabwean health sciences articles are dominated by researchers from outside Zimbabwe. The trend is, however, different in humanities. For instance, in 2012, out of a total of 51 authors who produced articles in the humanities, the majority (75%) had authors with a Zimbabwean affiliation only, 18% had an international affiliate, while 7% had both a Zimbabwean and an international affiliation.

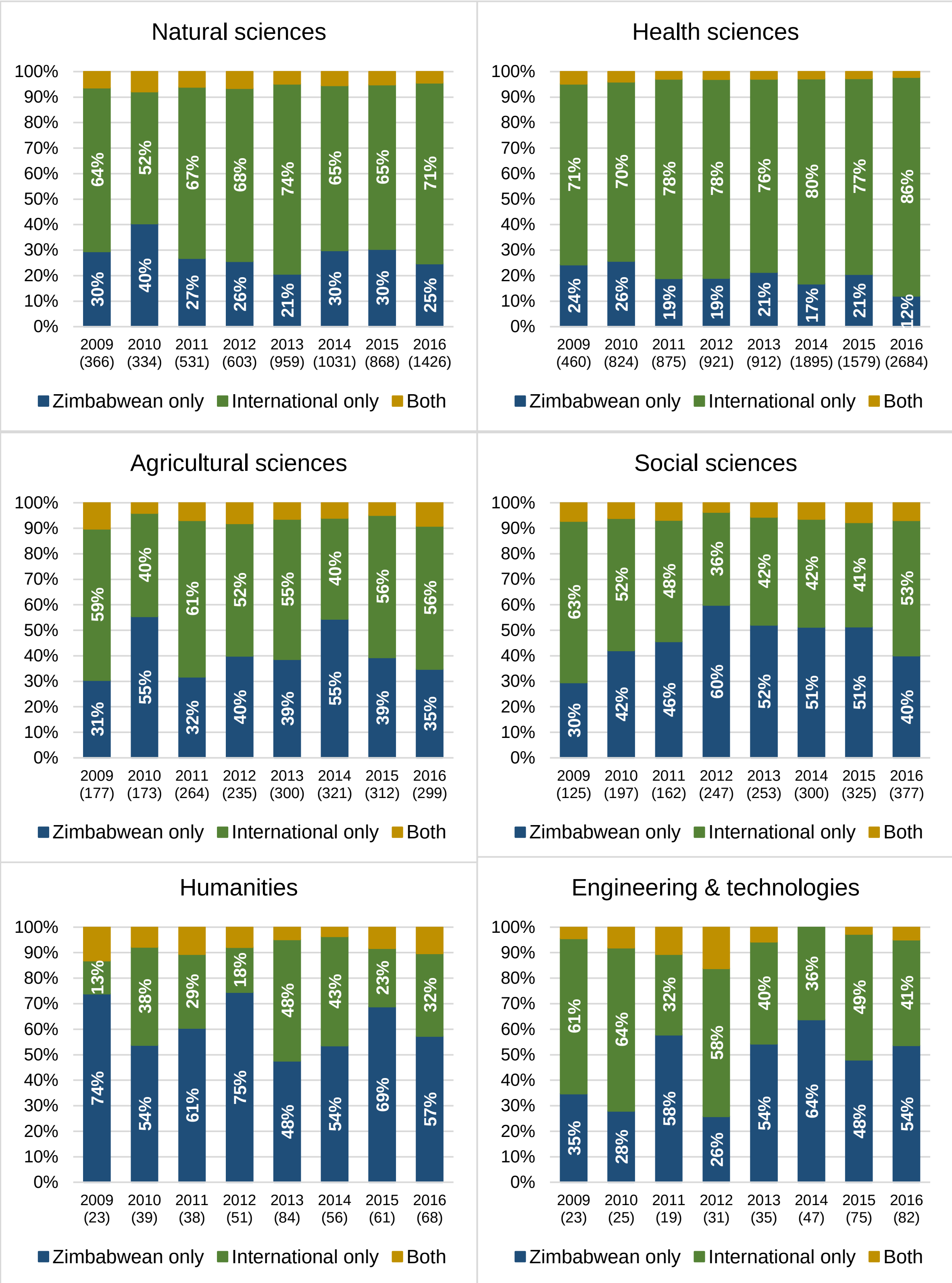

Figure 9.4: Distribution of address affiliations of all article authors, by year and broad field, 2009-2016

9.2.2 Profile of Zimbabwean authors in five national sectors

Figure 9.5 shows the distribution of Zimbabwean authors across the five national sectors. As can be seen, the highest concentration of Zimbabwean authors was in the university sector (78%), followed by the government sector (33%). Note that the percentages in Figure 9.5 exceed 100% because some authors published articles using addresses that are classifiable in more than one sector. For this reason, Table 9.2 highlights the extent of overlap between Zimbabwean authors in different national sectors.

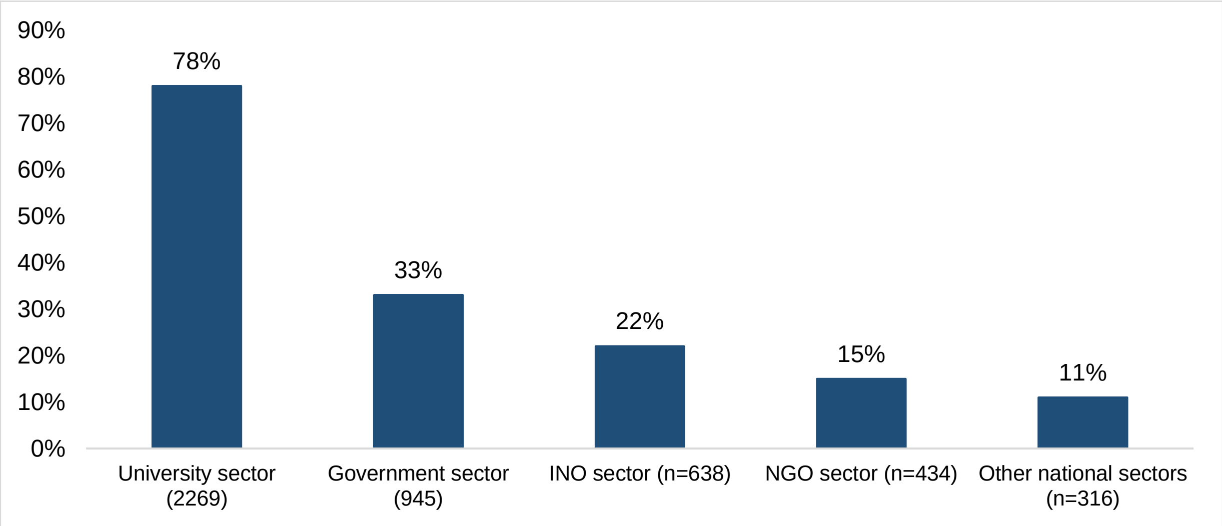

Figure 9.5: Distribution of Zimbabwean authors by national sector, 2009-2016

According to Table 9.2, 69% of authors in the government sector also published articles with a university address as their affiliation. The table further shows that 62% of authors in the category of 'other national sectors' (comprising authors from industry/businesses, private hospitals and clinics, private schools and training institutes, mission or faith-based hospitals, and unions and associations) also had articles with a university affiliation. One explanation for these large overlaps could be an issue of mobility, where researchers moved from one organisation to the other. The other reason could be an issue of double affiliation, where researchers are affiliated with institutions in both sectors at the same time.

Table 9.2: Extent of overlap of Zimbabwean authors in five national sectors, 2009-2016

	University sector (n=2269)	Government sector (n=945)	INO sector (n=638)	NGO sector (n=434)	Other national sectors (n=316)
University sector	--	69%	54%	55%	62%
Government sector	29%	--	48%	48%	35%
INO sector	15%	33%	--	32%	18%
NGO sector	11%	22%	22%	--	17%
Other national sectors	9%	12%	9%	13%	--

Figure 9.6 shows a comparative analysis of the annual number of articles vis-à-vis the annual number of authors that produced those articles in each of the five national sectors. The figure shows a general trend where the number of authors surpassed the number of articles produced. It shows an increase in the number of Zimbabwean authors and an increase in the number of articles produced by authors during the period under review. It also shows that the university sector had both the largest research workforce and the highest number of articles produced by national sectors.

Figure 9.7 illustrates the average number of articles per Zimbabwean author, by year and national sector. It shows that the government sector had the lowest ratios (i.e. 0.4 articles per author), meaning the sector had the highest number of Zimbabwean authors producing articles at any given point. For instance, in 2014, 306 authors were responsible for 120 articles produced during that year, as shown in Figure 9.6. The average number of articles per Zimbabwean author during that year was 0.4, as illustrated in Figure 9.7.

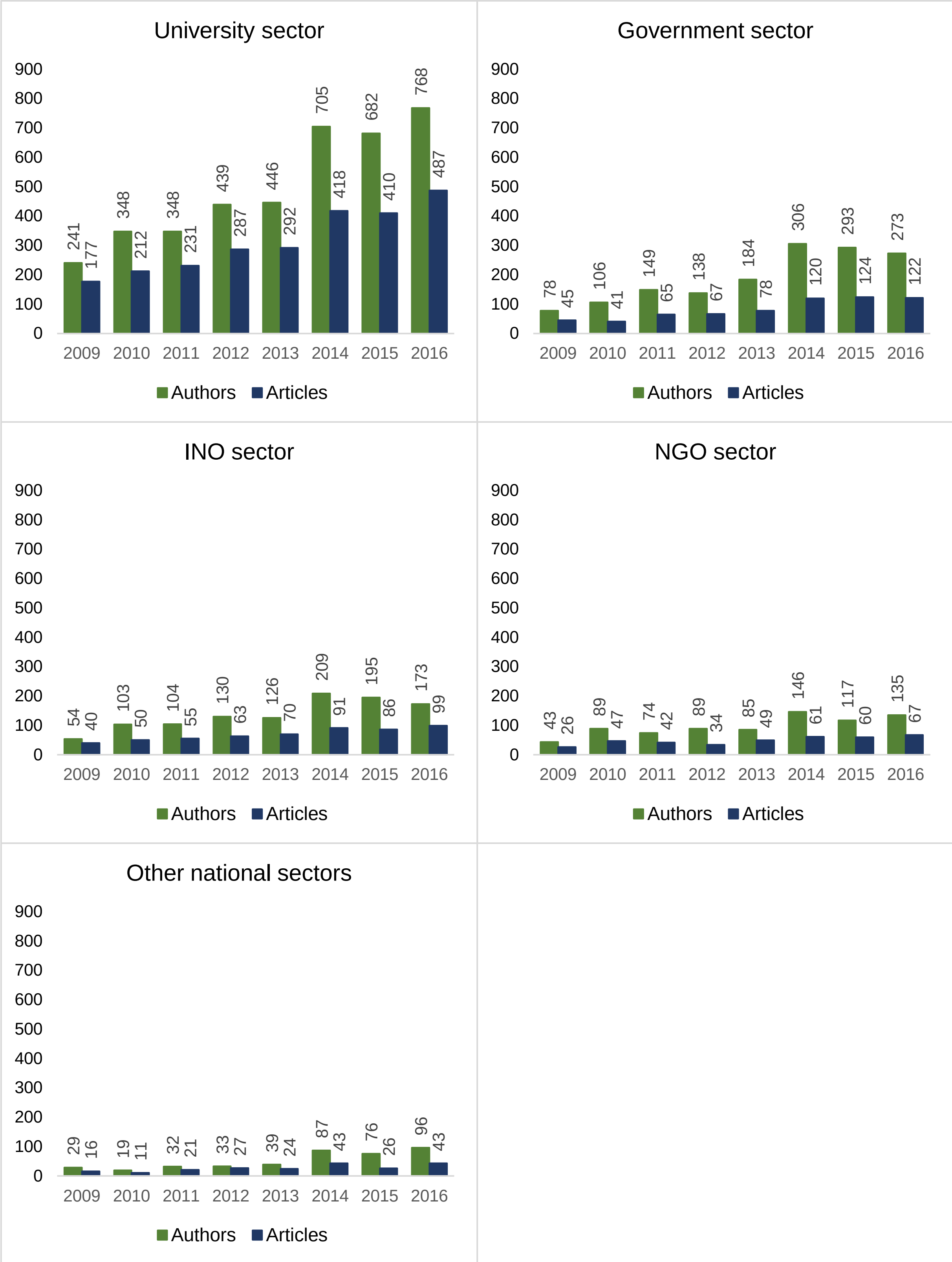

Figure 9.6: Comparative analysis of the annual number of articles vis-à-vis the annual number of authors that produced the articles, by year and national sector, 2009-2016

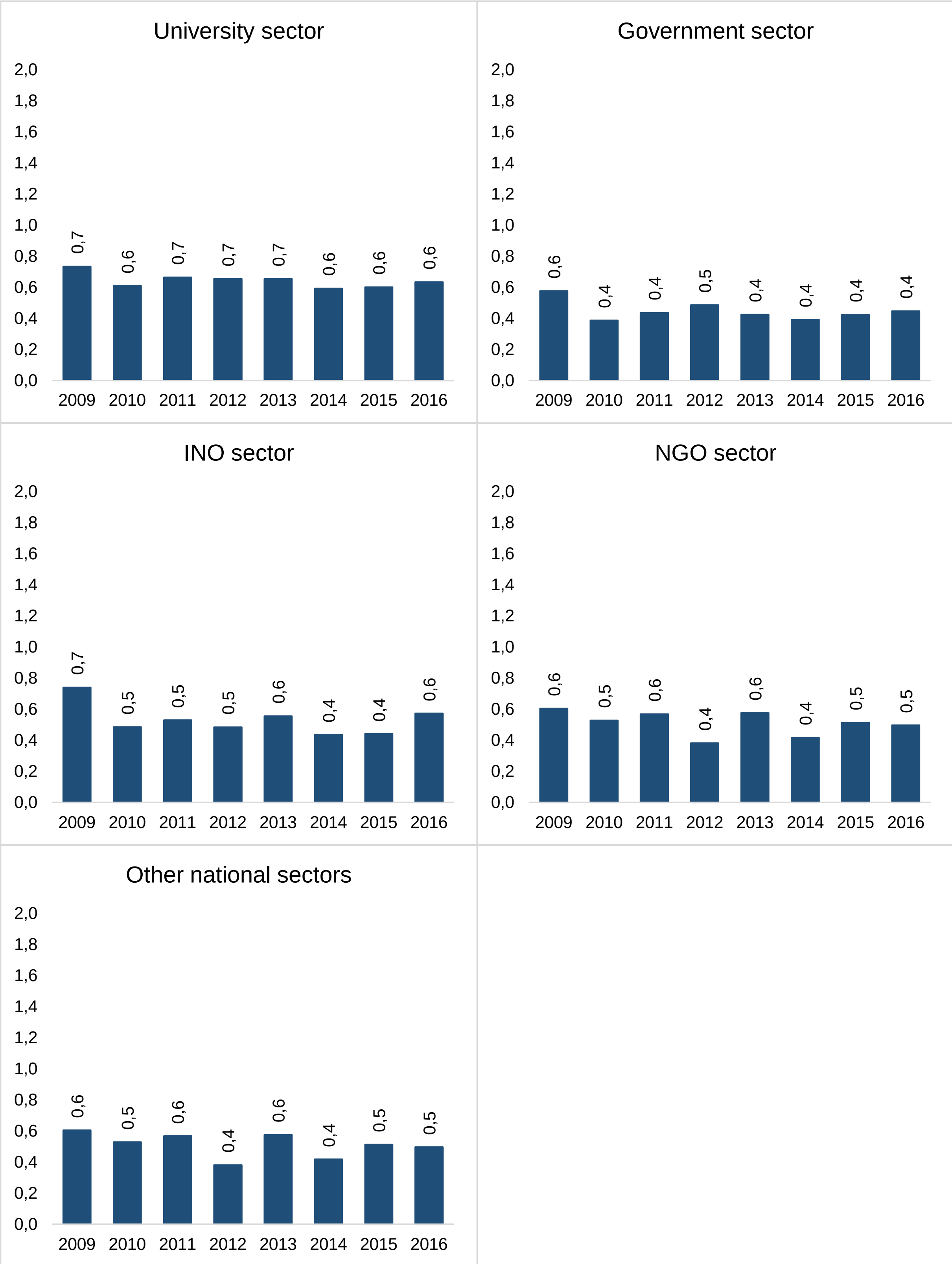

Figure 9.7 Average number of articles per Zimbabwean author, by year and national sector, 2009-2016

The focus now shifts to all authors, including international co-authors, responsible for the article output in each national sector during the period under review. As mentioned in Section 9.2.1, authors were classified into three mutually exclusive categories:

- Zimbabwean only
- International only
- Both Zimbabwean and international.

Figure 9.8 shows a breakdown of the distribution of address affiliations of all article authors by each national sector. The figure demonstrates that the majority of articles produced by each national sector was by authors with an international affiliation only. The figure shows that while the number of authors with an international affiliation only in the university sector ranged from 57% to 61%, the number of authors with an international affiliation in the 'international national organisation' (INO) sector ranged from 56% to 88%. This means that the INO sector had higher numbers of authors with an international affiliation only. The government sector had the highest record of authors in a single year with a Zimbabwean affiliation only: in 2010, out of a total of 182 authors responsible for articles produced, the majority (50%) had a Zimbabwean affiliation, 42% had an international affiliation only, while 8% had both an international and Zimbabwean affiliation.

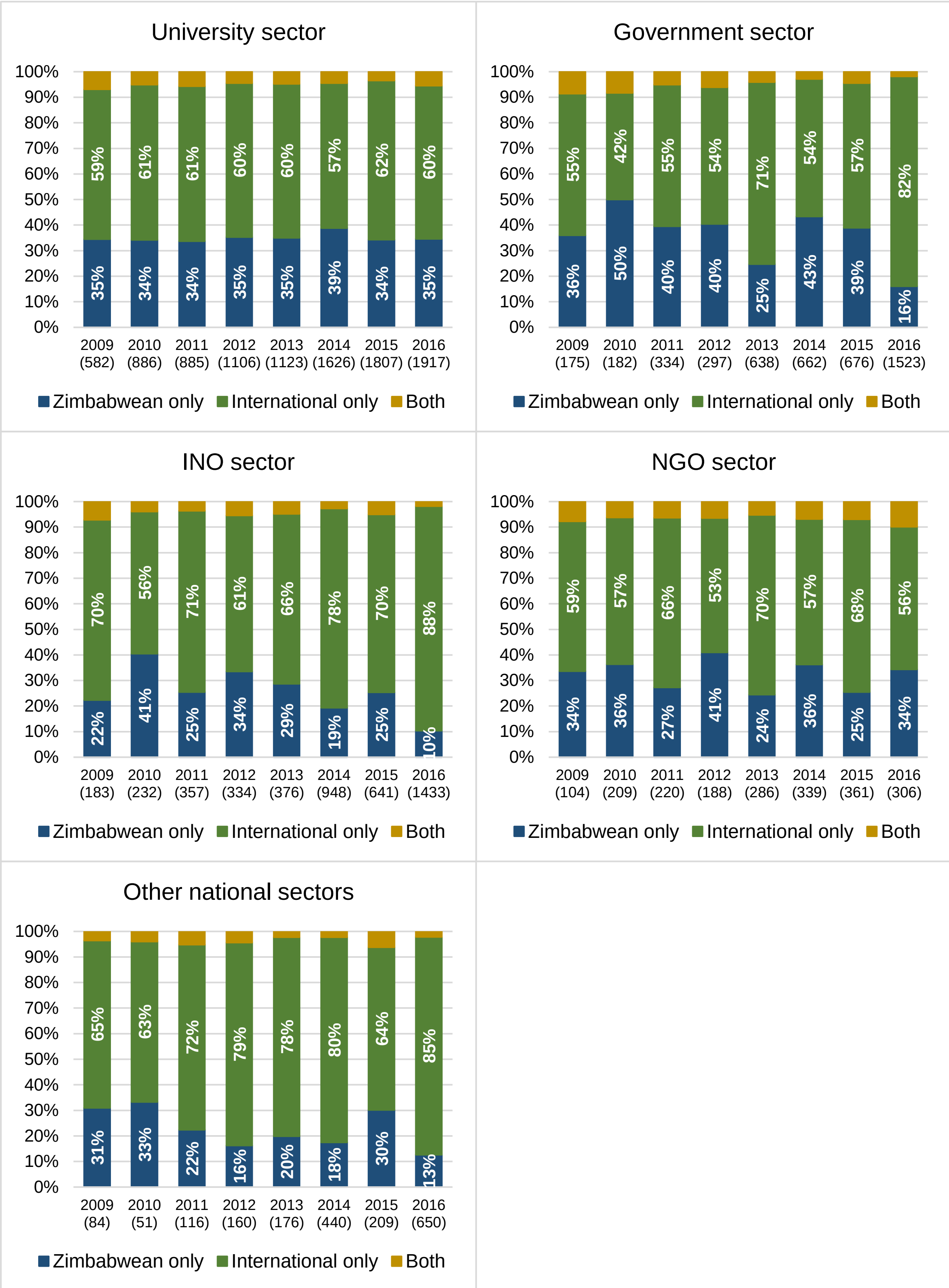

Figure 9.7: Distribution of address affiliations of article authors, by year and national sector, 2009-2016

9.3 National versus international collaboration of researchers in Zimbabwe

The previous section profiled the publishing research workforce in Zimbabwe across fields and sectors. This section highlights the modes of collaboration of those researchers. The results in this section are presented as a series of comparisons. The objective, as discussed in the introduction, is to determine whether and how profiles of co-authored articles difer from profiles of co-authoring authors. Both these profiles reflect research collaboration, however one indicator is framed in terms of articles while the other is framed in terms of authors. Table 9.3 shows an overall analysis of the modes of collaboration by researchers in Zimbabwe. As mentioned in Chapter 5, Step 14, The author-level dataset generated two main indicators, each divided into three sub-indicators, as follows:

- Main indicator 1: The percentage of Zimbabwean authors who co-authored at least one article in the period 2009-2016 ('% of Zimbabwean authors who co-authored articles').
    - Three sub-indicators for main indicator 1: The three parts are based on three mutually exclusive sets of authors: those who co-authored nationally only, internationally only, and both nationally and internationally.
- Main indicator 2: The average percentage of co-authored articles produced by a Zimbabwean author in the period 2009-2016 ('Mean % of co-authored articles per Zimbabwean author').
    - Three sub-indicators for main indicator 2: The three parts are again based on three mutually exclusive sets of co-authored articles: nationally co-authored only, internationally co-authored only, and both nationally and internationally co-authored.

The main indicators and sub-indicators for the article-level dataset appear in the first column of Table 9.3.

Table 9.3: National and international co-authorship in Zimbabwe: Comparison of indicators based on author-level and article-level datasets

Article-level indicators	%	Author-level indicators 1	%	Author-level indicators 2	%
MAIN INDICATORS					
% of Zimbabwean articles that are co-authored	89%	% of Zimbabwean authors who co-authored articles	95%	Mean % of co-authored articles per Zimbabwean author	93%
SUB-INDICATORS					
% of Zimbabwean articles that are nationally co-authored only	20%	% of Zimbabwean authors who co-authored articles nationally only	30%	Mean % of nationally co-authored articles (only) per Zimbabwean author	36%
% of Zimbabwean articles that are internationally co-authored only	37%	% of Zimbabwean authors who co-authored articles internationally only	13%	Mean % of internationally co-authored articles (only) per Zimbabwean author	16%
% of Zimbabwean articles that are both nationally and internationally co-authored	31%	% of Zimbabwean authors who co-authored articles both nationally and internationally	52%	Mean % of nationally and internationally co-authored articles (both) per Zimbabwean author	41%

Table 9.3 shows that analyses based on two different units of analysis display different bibliometric results. For instance, based on the main article-level indicator, it can be seen that 89% of all Zimbabwean articles produced between 2009 and 2016 were co-authored, while the main author-level indicator shows that during the same period, 95% of all Zimbabwean authors had co-authored articles. The table shows that 37% of Zimbabwean articles were produced through international collaboration only (the highest for the three sub-indicators in the article-level dataset). However, in the author-level dataset, both indicators place relatively less emphasis on international collaboration: only 13% of authors produced articles through international collaboration only and, on average, only 16% of a Zimbabwean author's article involved international collaboration only. Rather, the emphasis was on national collaboration. For instance, 30% of all Zimbabwean authors produced nationally co-authored articles only, while 52% of all Zimbabwean authors produced both nationally and internationally co-authored articles.

From the analysis in Table 9.3, it is revealed that the bulk of the authors in the country collaborated nationally. However, those who collaborated with international partners produced more articles. Figure 9.9 below shows a breakdown of the total number of co-authored articles in the country vis-à-vis the total number of authors producing those articles.

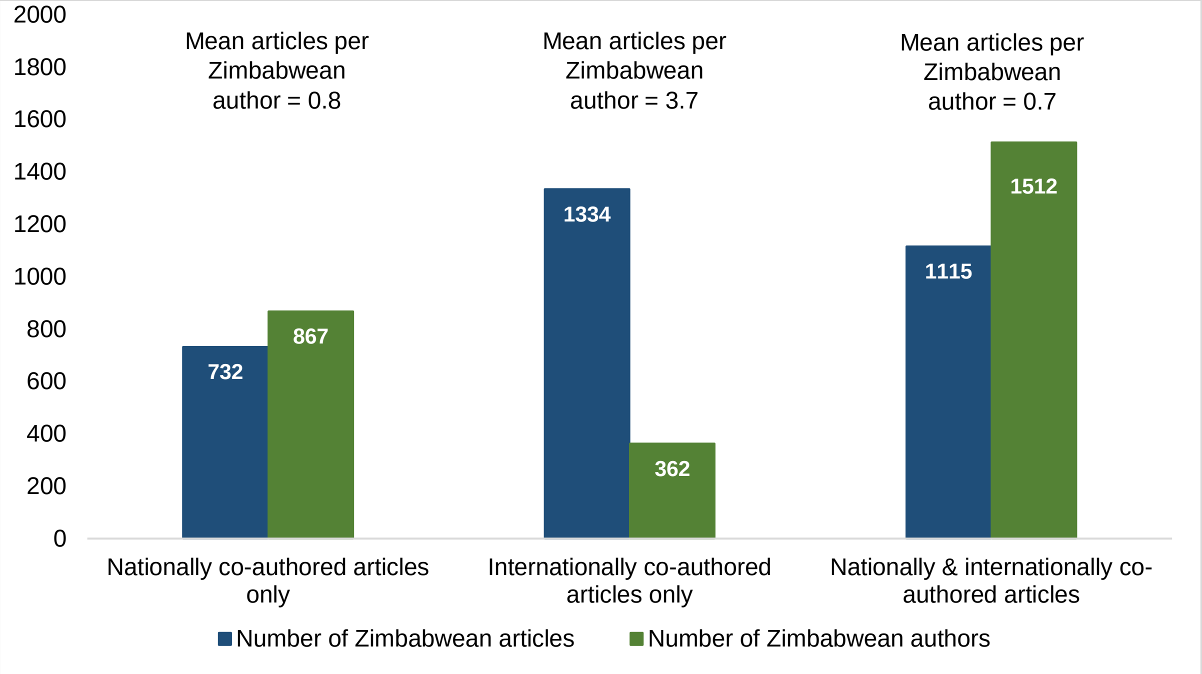

Figure 9.8: Mean number of articles produced by three categories of Zimbabwean authors, 2009-2016

Figure 9.9 shows the total number of Zimbabwean articles produced in three categories of co-authorship, as well as the total number of Zimbabwean authors in those three categories of co-authorship. As can be seen in the figure, the smallest number of authors (362) produced 1 334 articles through international co-authorship only. Authors in this category were the most productive as they produced, on average, 3.7 articles per author. Authors (1 512) producing articles (1 115) through both national and international co-authorship followed in terms of productivity, with a mean score of 0.7 articles per author. Authors (867) with articles (732) produced through national co-authorship only had the lowest mean score of 0.8.

9.3.1 National co-authorship of researchers in Zimbabwe

This section focuses on national co-authorship (i.e. the categories of 'national co-authorship only' and 'both national and international co-authorship') and provides a comparative analysis of the author-level and article-level datasets. Only one author-level indicator is reported on in this section (which corresponds to indicator 1 from Table 9.3). Table 9.4 below shows the types of national co-authorship by Zimbabwean researchers between 2009 and 2016, together with the types of national co-authorship of articles in the same period.

Based on the article-level dataset, it was found that the total percentage of Zimbabwean articles that involved national co-authorship only was 20% (a figure already encountered in

Table 9.3). The 20% is further broken down into 12% that involved intra-institutional co-authorship only, 1% that were generated through inter-institutional co-authorship only, and 7% produced through both intra- and inter-institutional co-authorship.

When an author-level dataset was analysed, it was found that the total percentage of Zimbabwean authors with articles produced through national co-authorship was 30% (again a figure already reported in Table 9.3). Of these, 17% of the Zimbabwean authors produced articles through intra-institutional co-authorship only, 2% produced articles through inter-institutional co-authorship, and 11% produced articles co-authored both intra and inter-institutional co-authorship. These results indicate that less than a third of all Zimbabwean authors (30%) participated in national co-authorship only. Co-authorship between different national institutions only was almost non-existent (2%) for authors practising national co-authorship. This observation is strongly supported by the article-level analysis as well, where only 1% of all articles were national co-authored between different national institutions only (inter-institutionally co-authored).

Table 9.4: National co-authorship within and between institutions in Zimbabwe: Indicators based on author-level and article-level datasets (national co-authorship only)

Article-level indicators	**%**	**Author-level indicators**	**%**
MAIN INDICATOR			
% of Zimbabwean articles that are nationally co-authored only	20%	% of Zimbabwean authors who co-authored articles nationally only	30%
SUB-INDICATORS			
% of Zimbabwean articles produced through intra-instituional co-autorship only	12%	% of Zimbabwean authors who produced articles through intra-instituional co-autorship only	17%
% of Zimbabwean articles that are produced through inter-institutional co-authorship only	1%	% of Zimbabwean authors who produced articles through inter-institutional co-authorship only	2%
% of Zimbabwean articles that are produced through both intra and inter-institutional co-authorship	7%	% of Zimbabwean authors who produced articles through both intra and inter-institutional co-authorship	11%

Table 9.4 shows the different types of national co-authorship in the absence of any co-occurring international co-authorship. In contrast, Table 9.5 presents a breakdown of national co-authorship for Zimbabwean authors who co-authored both nationally and internationally, and for articles involving both national and international co-authorship.

Table 9.5 shows that 31% of all Zimbabwean articles were both nationally and internationally co-authored. This percentage is broken down into three groups: one group comprising 16% indicates articles that involved intra-institutional co-authorship, together with researchers outside of Zimbabwe. Another group of 10% indicates articles that involved both intra and inter-institutional co-authorship, together with researchers outside of Zimbabwe. Marginal differences are seen when author-level indicators are used. For instance, 52% of Zimbabwean authors produced articles through both national and international co-authorship. Broken down into three groups, it can be seen that one group constituting 20% represents Zimbabwean authors generated through intra-institutional co-authorship together with researchers outside of Zimbabwe. Another group of 27% indicates Zimbabwean authors who generated through both intra and inter-institutional co-authorship, together with researchers from outside of Zimbabwe.

Table 9.5: National co-authorship within and between institutions in Zimbabwe: Indicators based on author-level and article-level datasets (both national and international co-authorship)

Article-level indicators	%	Author-level indicators	%
MAIN INDICATOR			
% of Zimbabwean articles that are both nationally and internationally co-authored	31%	% of Zimbabwean authors who co-authored articles both nationally and internationally	52%
SUB-INDICATORS			
% of Zimbabwean articles that are both nationally and internationally co-authored, where national co-authorship is within same institutions only (i.e intra-institutional co-uthorship)	16%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where national co-authorship is within same institutions only (i.e intra-institutional co-uthorship)	20%
% of Zimbabwean articles that are both nationally and internationally co-authored, where national co-authorship is between different institutions only (i.e inter-institutional co-authorship)	4%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where national co-authorship is between different institutions only (i.e inter-institutional co-authorship)	3%
% of Zimbabwean articles that are both nationally and internationally co-authored, where national co-authorship is both within same institutions and between different institutions (i.e intra and inter-institutional co-aouthrship)	10%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where national co-authorship is both within same institutions and between different institutions (i.e intra and inter-institutional co-aouthrship)	27%

9.3.2 International co-authorship of researchers in Zimbabwe

The focus now shifts to international co-authorship. An analysis of internationally co-authored articles only and Zimbabwean authors with internationally co-authored articles only is presented in Table 9.6. As already highlighted in Section 9.3, authors with internationally co-authored articles only were found to be the most productive in the country. In Table 9.6, the larger set (6%) of this group of authors co-author with individuals in Africa, while another 4% co-author with individuals from both the rest of Africa and the rest of the world. When only the article dataset is used to analyse the authorship patterns of researchers who collaborate with international partners only, it would show that the highest percentage of co-authored articles were those involving researchers from both the rest of Africa and the rest of the world. In terms of the two main indicators, there is already a significant discrepancy between the figures reported for the article-level analysis and the author-level analysis (37% versus 13%, respectively). The discrepancy was highlighted in Figure 9.9. One would therefore also observe salient differences between the sub-indicators for the article-level and author-level datasets, which is indeed the case.

Table 9.6: International co-authorship with rest of Africa and rest of world: Indicators based on author-level and article-level datasets (international co-authorship only)

Article-level indicators	%	Author-level indicators	%
MAIN INDICATOR			
% of Zimbabwean articles that are internationally co-authored only	37%	% of Zimbabwean authors who co-authored articles internationally only	13%
SUB-INDICATORS			
% of Zimbabwean articles that are internationally co-authored with rest of Africa only	11%	% of Zimbabwean authors who co-authored articles internationally with rest of Africa only	6%
% of Zimbabwean articles that are internationally co-authored with rest of world only	10%	% of Zimbabwean authors who co-authored articles internationally with rest of world only	3%
% of Zimbabwean articles that are internationally co-authored with both rest of Africa and rest of world	16%	% of Zimbabwean authors who co-authored articles internationally with both rest of Africa and rest of world	4%

Table 9.7 shows articles and authors with both national and international co-authorship. The table also shows a discrepancy between the figures reported for the article-level analysis and the author-level analysis (31% compared to 52%, respectively). There are also differences between the sub-indicators for the article-level and author-level datasets. For example, 7% of all Zimbabwean articles that were both nationally and internationally co-authored involved international co-authorship with the rest of Africa only, while 12% of all Zimbabwean authors who co-authored articles both nationally and internationally co-authored articles with the rest of Africa only.

Table 9.7: International co-authorship with rest of Africa and rest of world: Indicators based on author-level and article-level datasets (both national and international co-authorship only)

Article-level indicators	%	Author-level indicators	%
MAIN INDICATOR			
% of Zimbabwean articles that are both nationally and internationally co-authored	31%	% of Zimbabwean authors who co-authored articles both nationally and internationally	52%
SUB-INDICATORS			
% of Zimbabwean articles that are both nationally and internationally co-authored, where international co-authorship is with rest of Africa only	7%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where international co-authorship is with rest of Africa only	12%
% of Zimbabwean articles that are both nationally and internationally co-authored, where international co-authorship is with rest of world only	15%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where international co-authorship is with rest of world only	17%
% of Zimbabwean articles that are both nationally and internationally co-authored, where international co-authorship is with both rest of Africa and rest of world	9%	% of Zimbabwean authors who co-authored articles both nationally and internationally, where international co-authorship is with both rest of Africa and rest of world	20%

9.4 Zimbabwean researchers with dual national-international affiliations

It is noted that co-authorship can be conflated with co-affiliation. According to Sugimoto and Lariviere (2018), co-affiliation arises when a single individual is associated with more than one country in an article. Authors with such affiliations usually pose a challenge in bibliometric analysis. With this in mind, an analysis of authors with dual (national-foreign) affiliations was undertaken. The study found that out of a total of 2 896 Zimbabwean authors, 400 (14%) also published under an international affiliation in the same article. A breakdown of the field classification of these authors is provided in Figure 9.10. As can be seen, the majority of authors with dual national-international affiliations are in the natural sciences (244 or 61%), followed by those in the health sciences (180 or 45%). The percentages in Table 5.10 do not add up to 100% because of overlaps of author classification in the different fields. As mentioned earlier, overlaps could be a result of authors publishing in journals with dual field classifications.

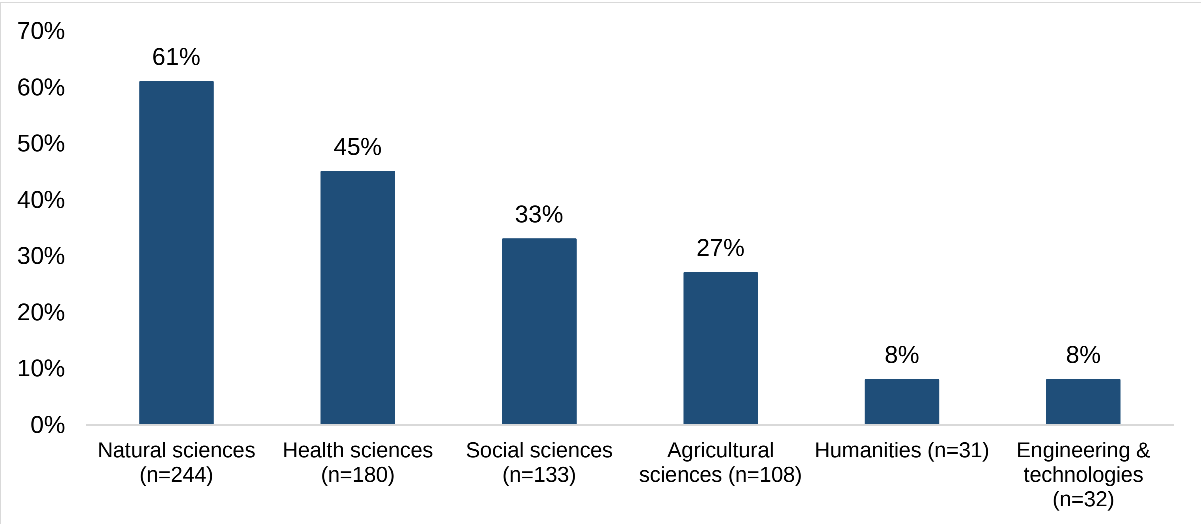

Figure 9.9: Distribution of Zimbabwean authors with dual national-international affiliations, by broad field, 2009-2016

Figure 9.11 below shows that the largest volume (322 or 81%) of Zimbabwean authors with dual national-international affiliations are in the university sector. The second largest concentration of these authors is in the government sector (163 or 41%). It is important to note that these authors might also have more than one Zimbabwean address; hence, the percentages in the figure exceed 100%.

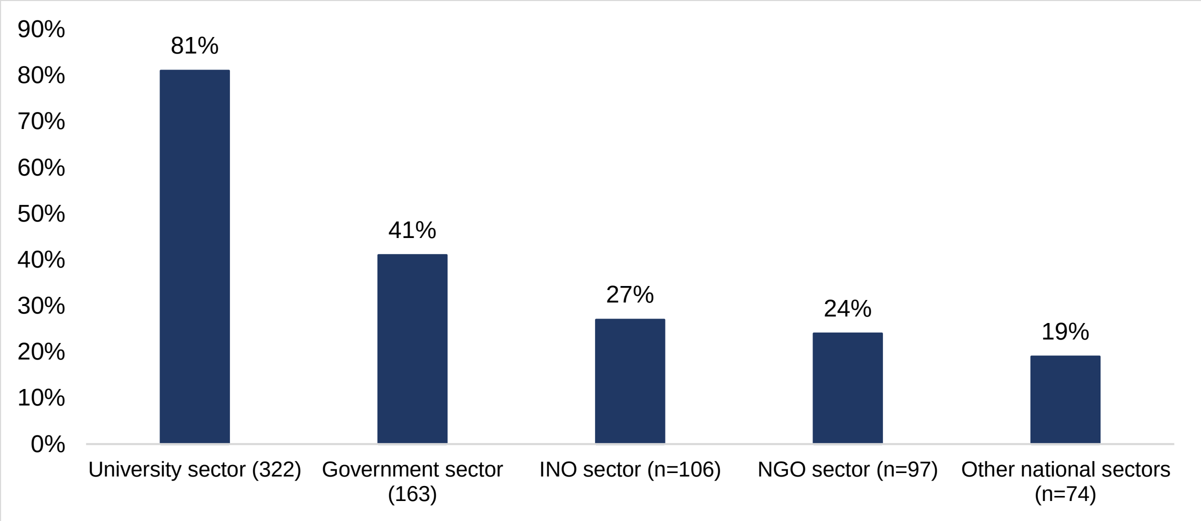

Figure 9.10: Distribution of Zimbabwean authors with dual national-international affiliations, by national sector, 2009-2016

Finally, the modes of collaboration of Zimbabwean authors with dual national-international affiliations are provided in Figure 9.12. The figure is based on 370 Zimbabwean authors (i.e. 93% of the 400 with dual national-international affiliations) who produced co-authored articles. Of this 370, the majority (76%) had articles involving both national and international co-authorship, 23% had articles with international co-authorship only, and 3% articles involving national co-authorship only. These results indicate that Zimbabwean authors with dual-national international affiliations produced almost all of their co-authored articles through international collaboration (99%), and incorporated other Zimbabwean researchers into those collaborations.

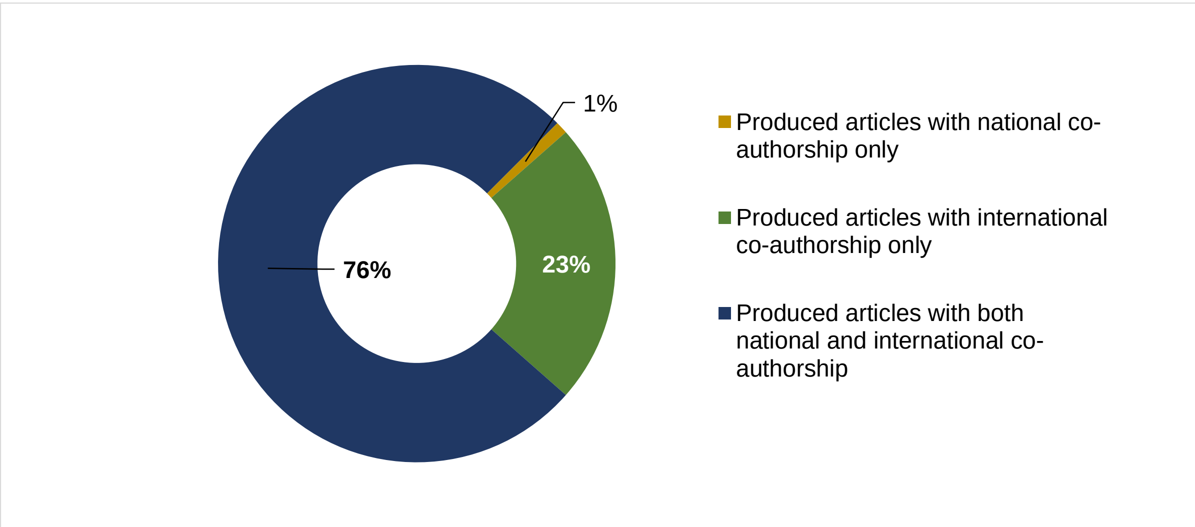

Figure 9.11: Types of co-authorship of Zimbabwean authors with dual national-international affiliations, 2009-2016 (n=370)

9.5 Conclusion

This section provides a brief summary of the results discussed in the chapter. A more detailed discussion is provided in Chapter 11. As explained in the introduction to this chapter, the main goal was to determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed compared to when author-level datasets are analysed. The results showed that analyses based on two different units of analysis produce different bibliometric results. For instance, based on the main article-level indicator, it was found that 89% of all Zimbabwean articles produced between 2009 and 2016 were co-authored, while the main author-level indicator showed that 95% of all Zimbabwean authors produced co-authored articles during that same period. What this means is that although the two sets of indicators generally reveal a similar pattern of results, the results are not identical. One explanation for this relates to the fact that a single productive author can produce many articles. A decision regarding which finding to apply in a practical context (e.g. research policy context) is thus a matter of emphasis – whether to emphasise the research performance (volumes of articles as output) or the research performer (the authors and their publishing characteristics).

Not only did the two different units of analysis produce different bibliometric results, they also highlighted the most productive authors. For instance, it was shown that the smallest number of authors (362) produced 1 334 articles through international co-authorship only. Authors in this category were the most productive as they produced, on average, 3.7 articles per author. Authors who produced both national and international co-authorship followed in terms of productivity, with a mean score of 0.7 articles per author. Authors with articles produced through national co-authorship only had the lowest mean score of 0.8.

The results in the chapter also showed that the majority of Zimbabwean authors (i.e not mutually exclusive) were concentrated in the natural sciences. The second largest concentration of authors during the period under review was in the health sciences followed by the social sciences. In terms of sector classification, the highest concentration of Zimbabwean authors was in the university sector, followed by those in the government sector. In addition, it was shown that the largest volume of Zimbabwean authors with dual national-international affiliations was in the university sector, followed by the government sector. Overall, with the exception of the humanities, the highest number of authors responsible for article production in Zimbabwe had an international affiliation. This indicates that production of Zimbabwean articles is largely dominated by researchers from outside of Zimbabwe.

CHAPTER 10

Research collaboration and related activities in Zimbabwe: Results of a survey

10.1 Introduction

The previous chapters presented bibliometric analyses of the patterns of research output and collaboration in Zimbabwe, as well as profiles of research output and collaboration of Zimbabwean researchers who are article authors. This chapter presents the findings from an online survey of researchers in Zimbabwe. The survey allowed for additional insights into collaboration patterns and experiences of Zimbabwean researchers that could not be captured by the bibliometric analyses. To this end, the survey sought to answer two broad research questions:

1. What are the reasons for research collaboration?
2. What challenges are faced by researchers in Zimbabwe when engaging in research collaboration?

Both the reasons for and challenges of research collaboration have been analysed in terms of differences of regard to gender, age, field, sector and career stage.

This chapter is structured into eight sections. Section 10.2 presents the demographic profiles of the researchers who responded to the survey. This is followed, in Section 10.3, by an analysis of article co-authorship and research collaboration. The study sought to solicit information on the article-authorship practices of researchers in Zimbabwe, determining how regularly they engaged in research collaboration. Section 10.4 focuses on the geographic patterns of research collaboration. Sections 10.5 provides a detailed analysis of the reasons for engaging in research collaboration. Section 10.6 highlights the aspects considered by Zimbabwean researchers in the selection of collaborators. Section 10.7 focuses on the challenges faced during collaborations.

Co-authorship can be considered as a proxy for research collaboration or, at best, seen as one specific form of research collaboration. Data sharing might be considered to be another type of collaboration in research. For these reasons, a focus on disputes faced with regard to authorship and data ownership is also warranted. Section 10.8 provides information about the authorship disputes faced by researchers in Zimbabwe, while Section 10.9 addresses issues related to data ownership and data sharing. The conclusions drawn from the survey results are presented in Section 10.10.

The demographic details of researchers who responded to the online survey are presented in the section that follows. It is important to note, as mentioned in Chapter 5 that a total of 316 researchers responded to the questionnaire. This translated into a survey response rate of 13% of the 2 392 email addresses distributed. Although 316 responses were received, the number of valid responses ranged from 220 to 259 as some questions were not fully completed.

10.2 Demographics of survey respondents

Out of a total of 237 respondents who specified their gender, a quarter, 59 (25%), were female and 178 (75%) were male. Table 10.1 shows the distribution of all respondents by age, field, sector, highest level of qualification, and by research career stage. As can be seen, the majority of respondents (101) who completed the survey were 40 years of age or younger. It can also be seen that the majority of respondents (121) had a master's degree as their highest qualification level. Most of the respondents were from the university sector and were concentrated in the field of social sciences. In summary, about half of the respondents who completed the survey were young scientists. This could mean that, at the time of the study, it was mostly younger researchers who took the time to complete the survey.

Table 10.1: Demographic details of survey respondents, by gender

Demographics	Female		Male		Total	
	Count	%	Count	%	Count	%
Age						
≤40	24	44%	77	48%	101	47%
41-50	17	32%	51	32%	68	32%
51-60	10	19%	25	16%	35	16%
Over	3	6%	7	4%	10	5%
Total	54	100%	160	100%	214	100%
Highest academic qualification						
Master's or equivalent	29	50%	92	53%	121	53%
PhD or equivalent	29	50%	80	47%	109	47%
Total	58	100%	172	100%	230	100%
Research career stage						
First stage researcher	25	42%	89	50%	114	48%
Recognised researcher	15	25%	28	16%	43	18%
Established researcher	10	17%	38	22%	48	20%
Leading researcher	9	15%	22	12%	31	13%
Total	59	100%	177	100%	236	100%
Sector						
University	43	75%	147	84%	190	82%
Government organisatio	4	7%	10	6%	14	6%
Public research organisation (not university or government)	4	7%	6	3%	10	4%
Non-governmental organisation	5	7%	7	4%	12	5%
Industry/business	1	2%	6	3%	7	3%
Total	57	100%	176	100%	233	100%
Field						
Agricultural sciences	4	7%	20	12%	24	10%
Health sciences	21	36%	27	16%	48	21%
Natural sciences	11	33%	44	25%	55	24%
Social sciences	19	33%	71	41%	90	39%
Humanities	3	5%	12	7%	15	6%
Total	58	100%	174	100%	232	100%

Note: Percentages add to 100% in the columns.

10.3 Article co-authorship and research collaboration

The study sought to solicit information on the article-authorship practices of researchers in Zimbabwe; that is, whether they produced single-authored, co-authored or both single- and co-authored articles. The purpose of including this question in the survey was to find out whether there would be any correspondence between the survey and the bibliometric results. In this regard, respondents were asked to describe their article-authorship practices by indicating whether they produced (i) mostly single-authored articles, (ii) mostly co-authored articles, or (iii) both single- and co-authored articles (about evenly divided). A total of 256 researchers responded to this question. The responses are presented in Figure 10.1.

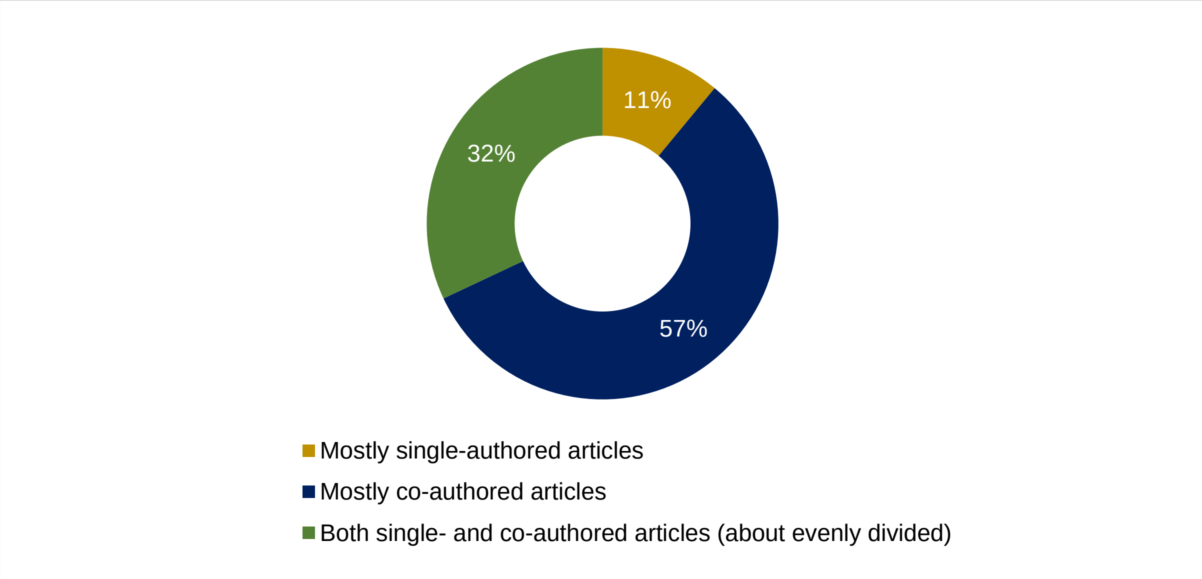

Figure 10.1: Article co-authorship practices of survey respondents (n=256)

As can be seen in the figure, the majority, 57%, of the respondents reported that most of their articles were produced through co-authorship, 32% said most of their articles involved both single- authorship and co-authorship, while 11% reported that most of their articles were single-authored.

10.3.1 Article co-authorship in the survey vis-à-vis the bibliometric dataset of authors

The distribution of co-authorship among the survey respondents (Figure 10.1 above) was compared to a similar distribution for Zimbabwean authors in the author-level dataset, for the period 2012-2016. The latter period was selected since a portion of the names of potential survey respondents was gathered from the list of Zimbabwean authors with articles published between 2012 and 2016 in the bibliometric database (see Chapter 5, Step 5). The results of the comparison are presented in Table 10.2.

Table 10.2: Article co-authorship of researchers in Zimbabwe: A comparison of the survey and bibliometric results

	Survey respondents (n=256)				Article authors, 2012-2016 (n=2 658)	
	Count	%			Count	%
Mostly single-authored articles	29	11%		Single-authored articles only	120	5%
Mostly co-authored articles	145	57%		Co-authored articles only	2186	91%
Both single- and co-authored articles (about evenly divided)	82	32%		Both single- and co-authored articles	89	4%

Table 10.2 shows notable differences between the bibliometric and survey results. While 57% of respondents in the survey reported that they produced mostly co-authored articles, the bibliometric results revealed that between 2012 and 2016, 91% of Zimbabwean authors produced co-authored articles only, and only 4% produced both single- and co-authored articles. One plausible explanation for this difference could be that some of the survey respondents had articles that were not included in the bibliometric data. This could be the case since survey respondents were also identified via the websites of universities and other research institutions. Another explanation for these differences could simply be an issue of semantics. This is the case because in the survey the word 'mostly' was used, which could have been interpreted by respondents as referring to either 'many of' or 'only' the articles of interest. Whatever the reason, the survey results most probably under-represent researchers who published co-authored articles only, whereas authors in the categories of 'single-authored' and both 'single- and co-authored' are well represented in the survey. On the other hand, 89% of the survey respondents published some form of co-authored article (i.e. either co-authored only or both single- and co-authored). The corresponding figure from the bibliometric component is 95% which means that the broader category of co-authoring researchers seems to be well represented in the survey.

10.3.2 Frequency and origin of research collaboration

The survey respondents were asked to indicate how regularly they engage in research collaboration. A 5-point rating scale was used: 'always', 'often', 'sometimes', 'seldom', and 'never'. The distribution of responses is shown in Figure 10.2. As can be seen, out of a total of 259 researchers who responded to this question, 9% had never engaged in research collaboration. The 'rest' had collaborated in various degrees, from always to sometimes.

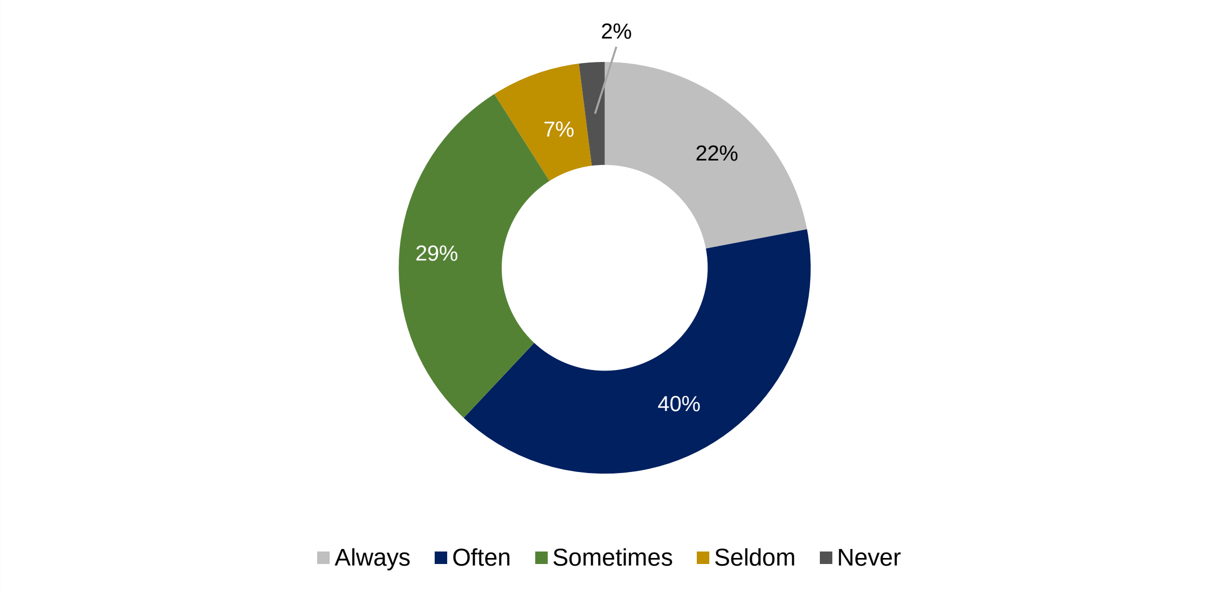

Figure 10.2: Frequency of research collaboration, as reported in the survey (n=259)

In further analyses in this chapter, only three categories are reported. Specifically, the 'always' and 'often' categories have been combined as have the 'seldom' and 'never' categories. The new categories are 'always/often', 'sometimes', and 'seldom/never'.

A breakdown of how regularly Zimbabwean researchers engaged in research collaboration, by different sets of demographic details, is presented in Table 10.3. The focus here is on respondents who said they seldom or never engaged in research collaboration. All shaded items represent the highest counts of respondents (i.e. based on the demographic details), who seldom or never engaged in research collaboration. Table 10.3 shows, for instance, that, in overall, young scientists had the highest counts of individuals who reported that they seldom/never engaged in research collaboration. For instance, based on highest level of qualification, respondents with a master's degree 14 (12%), had higher counts of individuals who seldom or never engaged in research collaboration. Additionally, first stage researchers 15 (13%), had the highest counts of individuals who seldom/never engaged in research collaboration.

Table 10.3: Frequency of research collaboration, by demographic details of survey respondents

Demographic details	Always/Often		Sometimes		Seldom/Never	
	Count	%	Count	%	Count	%
Age						
≤40	66	65%	28	28%	7	7%
41-50	37	54%	25	37%	6	9%
51-60	19	54%	12	34%	4	11%
Over 60	8	80%	0	0%	2	20%
Highest academic qualification						
Masters or equivalent	69	57%	38	31%	14	12%
PhD or equivalent	72	66%	30	28%	7	6%
Research career stage						
First stage researcher	64	56%	35	31%	15	13%
Recognised researcher	28	65%	13	30%	2	5%
Established researcher	30	63%	13	27%	5	10%
Leading researcher	22	71%	9	29%	0	0%
Sector						
University	116	61%	54	28%	20	11%
Government organisation	6	43%	6	43%	2	14%
Public research organisation (not university or government)	7	70%	3	30%	0	0%
Non-governmental organisation	10	83%	2	17%	0	0%
Industry/business	4	57%	3	43%	0	0%
Field						
Agricultural sciences	19	79%	5	21%	0	0%
Health sciences	36	75%	10	21%	2	4%
Natural sciences	36	66%	15	27%	4	7%
Social sciences	47	52%	32	36%	11	12%
Humanities	3	20%	7	47%	5	33%

Note: Percentages add to 100% in the rows.

The 24 respondents who seldom/never engaged in research collaboration were asked in an open-ended question to provide reasons for not undertaking collaborative research. Twenty-two responded to this question. The list of answers was produced in SPSS and exported to Excel for manual coding. Common themes in the responses were identified and each theme was assigned a label. The labels given were: (i) too heavy workload, (ii) lack of resources, (iii) lack of incentives and rewards, and (iv) bad collaboration experiences.

The category of '**too heavy workload**' was used to refer to all researchers who stated that they did not have time to engage in research collaboration because of other work duties. Six of the 22 respondents stated that they found it difficult to balance teaching and research. One respondent had this to say:

> *"… because of the workloads at work, one does not have any time to engage in relevant research. One may have interest in a particular topic but may struggle with having the time to conduct it effectively."*

All responses that cited lack of resources, lack of funding and lack of opportunities to engage in collaborative research were assigned the label '**lack of resources**'. Five respondents reported that lack of resources and lack of opportunities to engage in research collaboration hindered them from engaging in research collaboration. Statements such as "*lack of funding to undertake research*" and "*lack of resources to engage in research*" were made.

Responses that had to do with rewards for engaging in research collaboration were grouped under '**lack of incentives and rewards**'. Respondents in this category stated that they were not motivated to engage in any form of research as doing so did not bring any rewards. Other respondents cast blame on institutional policies and claimed that some promotional policies prompted them to publish single-authored articles. The reason, as stated by one respondent, was: "… *co-published articles are regarded as half-articles when it comes to promotions. Resultantly, I am forced to go solo*."

The last category descriptor, '**bad collaboration experiences**', was assigned to responses that highlighted negative experiences during past collaborations. Bad research collaboration experiences made researchers sceptical about engaging in further collaborative research. One respondent, who expressed fears of being taken advantage of, had this to say: "*I have been discouraged by people I thought were senior scholars who shoot down my then dreamy ideas."* The respondent went on to say: *"I would rather take full responsibility for shortcomings of my work instead of being blindsided and be tarnished by someone else's poor reading of a paper, a concept or an argument."*

Another bad experience highlighted was that of collaborators failing to deliver work as agreed. For instance, "*one ends up carrying parasitic colleagues who do not pull their weight and meet their targets*." Besides bad collaboration experiences, some respondents had other personal reasons for not engaging in collaborative research. One such case was a respondent who said: "*I was busy undergoing master's studies so preferred to do research after* [that] *without much pressure*."

Respondents who indicated that they engaged in research collaboration were asked to reflect on one project they had worked on in the past years, prior to 2018. They were then asked to select from a list of ten variables how that collaboration came about. The frequency distribution of responses is presented in Figure 10.3

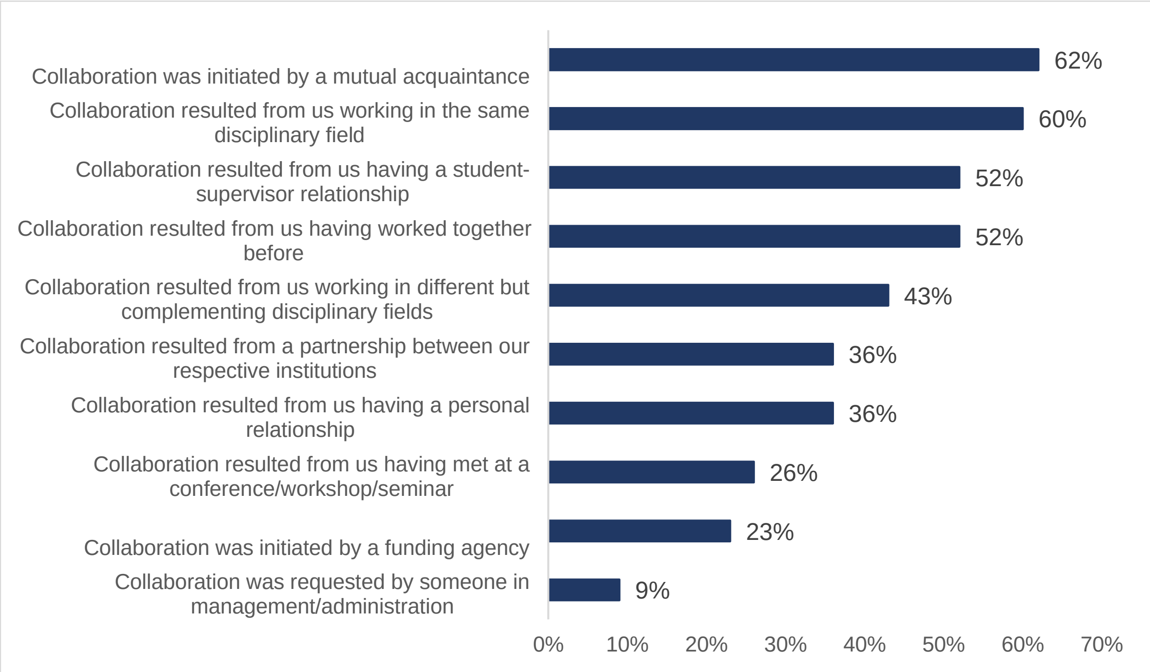

Figure 10.3: Origin of research collaboration

Figure 10.3 shows that most cases of research collaboration resulted from being initiated by a mutual acquaintance (62%), and from researchers having worked in the same disciplinary field (60%). Collaboration resulting from having a student-supervisor relationship (52%) was also frequently selected as an origin of research collaboration. This could be the case as students tend to be publish work with their respective supervisors. Collaboration being requested by someone in management (9%) was the least selected.

10.3.3 Correspondence between article co-authorship and research collaboration

The focus is now on the correspondence between article co-authorship and research collaboration. It is noted, as already reflected in the literature, that, article co-authorship and research collaboration are not synonymous. Collaboration does not always lead to co-authorship. To understand how respondents regarded research collaboration and article co-authorship, a cross tabulation was performed to show the correspondence between the two. The results of the cross tabulation are presented in Figure 10.4.

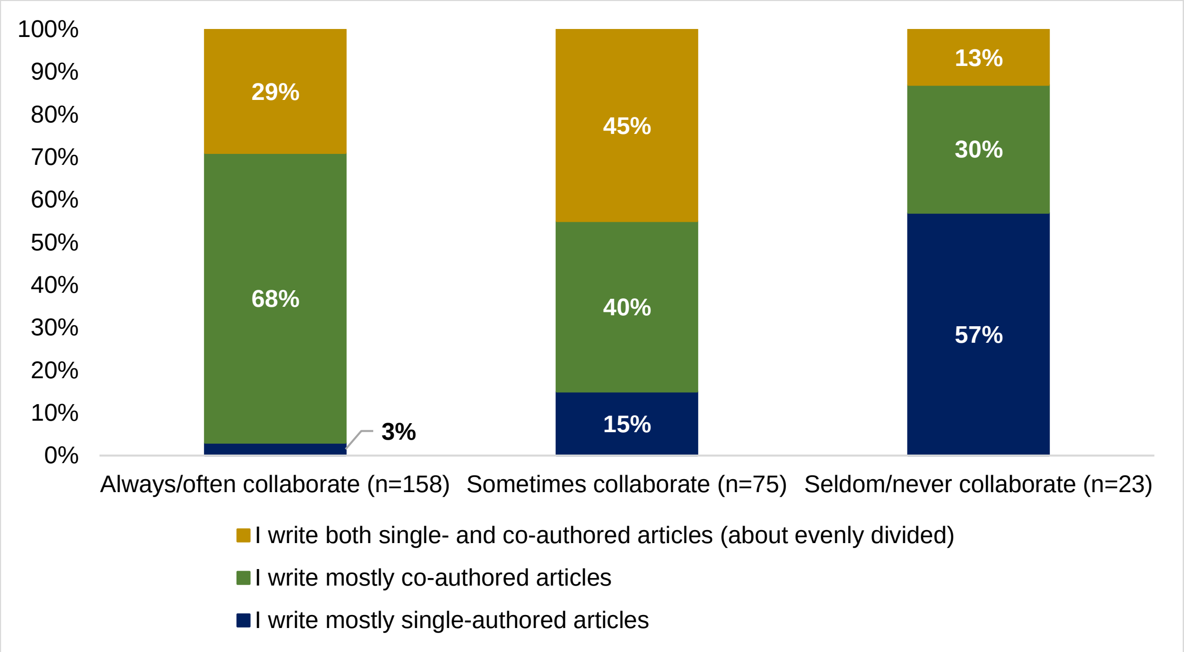

Figure 10.4: Cross-tabulation between frequency of research collaboration and article co-authorship

The following statistically significant differences ($p<0.05$) were found, based on a series of Bonferroni tests for comparison of proportions:

- "Always/often collaborate" (68% mostly co-authored articles) > "Sometimes collaborate" (40% mostly co-authored articles)
- "Always/often collaborate" (68% mostly co-authored articles) > "Seldom/never collaborate" (30% mostly co-authored articles)
- "Sometimes collaborate" (15% mostly single-authored articles) > "Always/often collaborate" (3% mostly single-authored articles)
- "Sometimes collaborate" (45% both single- and co-authored articles) > "Always/often collaborate" (29% both single- and co-authored articles)
- "Sometimes collaborate" (45% both single- and co-authored articles) > "Seldom/never collaborate" (13% both single- and co-authored articles)
- "Seldom/never collaborate" (57% mostly single-authored articles) > "Always/often collaborate" (3% mostly single-authored articles)
- "Seldom/never collaborate" (57% mostly single-authored articles) > "Sometimes collaborate" (15% mostly single-authored articles)

The two categories of co-authorship combined shows a strong alignment between research collaboration and co-authorship. Ninety-seven percent of the 158 respondents who collaborated research-wise, either always or often, also co-authored articles. The largest share of single-authored articles (57%) was found among the 23 respondents who never or seldom collaborated in research, implying that this subset equated research collaboration with article co-authorship. However, the fact that only 30% of the 23 respondents (meaning seven respondents) who seldom or never collaborated also produced mostly co-authored articles, implies that only for a small number of respondents' research collaboration was seen as something different than article co-authorship. It can thus be assumed that the respondents' reflections on research collaboration in the survey to a large extent imply reflections on co-authorship and the research processes underlying and supporting co-authorship.

10.4 Geographic patterns of research collaboration

This section provides information on the geographic patterns of Zimbabwe's research collaboration; in other words, the geographic location of the individuals with whom they collaborate. Although the bibliometric chapters already highlighted the geographic patterns of research collaboration in Zimbabwe, those chapters did not present the demographic details of the Zimbabwean researchers involved in the different forms of collaboration. The survey results therefore complement the bibliometric data by showing the geographic patterns of collaboration based on the age, research career stage and the highest level of qualification of researchers, as well as the country where the highest qualification was obtained.

Table 10.4 presents the geographic patterns of research collaboration in Zimbabwe, based on the survey results. The respondents were asked to specify how regularly they collaborated with individuals in eight different locations.

Table 10.4: Frequency of research collaboration with individuals in different geographic locations

Geographic locations	Frequency of research collaboration		
	Always/ often	Sometimes	Seldom/ never
Individuals from my own organisation in Zimbabwe (n=227)	70%	22%	8%
Individuals from other organisations in Zimbabwe (n=228)	32%	41%	27%
Individuals in South Africa (n=224)	22%	33%	45%
Individuals in the rest of Africa (South Africa excluded) (n=226)	9%	27%	64%
Individuals in Europe (n=225)	12%	24%	64%
Individuals in the US (n=218)	10%	14%	77%
Individuals in Asia (n=217)	4%	6%	90%
Individuals elsewhere in the world (n=220)	3%	16%	81%

Note: Percentages add to 100% in the rows.

Based on Table 10.4, it is observed that respondents regularly collaborated with individuals from Zimbabwe and South Africa. For instance, out of a total of 227 respondents, 70% reported that they always collaborated with individuals from within their own institutions. Out of a total of 224 respondents, 22% reported that they collaborated with individuals from South Africa, while 33% also said they sometimes collaborated with individuals located in South Africa. The table shows that collaboration with individuals from outside of Africa was relatively less. For instance, referring to the US, out of a total of 218 respondents, 77% said they seldom/never collaborated with individuals in the US, 14% said they sometimes collaborated, while 10% said they always collaborated with individuals with located in the US. Similarly, respondents revealed that they collaborate with individuals in Asia.

For further analyses, it was assumed that the ‘always/often’ and ‘sometimes’ categories indicated the presence of collaboration and the ‘seldom/never’ category the absence of collaboration. The eight geographic locations in Table 10.4 (constituting separate variables in the SPSS dataset) were converted into a single variable comprising the following five mutually exclusive categories, each representing a particular region or combination of regions:

- Zimbabwe only
- Zimbabwe and rest of Africa
- Zimbabwe and rest of world
- Zimbabwe, rest of Africa and rest of world
- Outside Zimbabwe only.

Figure 10.5 shows the extent of collaboration with individuals in each of the five regions. As can be seen, 37% of the respondents reported that they collaborated with individuals in Zimbabwe (ZW), the rest of Africa (RoA), and the rest of the world (RoW). A further 29% said they collaborated with individuals in Zimbabwe only, while 6% collaborated only with individuals outside of Zimbabwe.

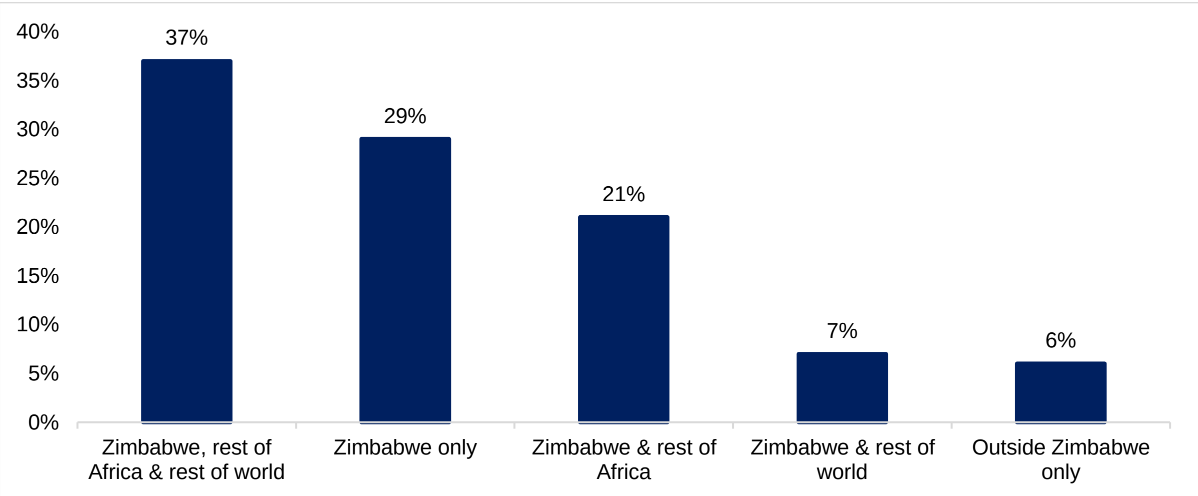

Figure 10.5: Extent of research collaboration with individuals in each of five regions (n=235)

Table 10.5 shows the regional patterns of collaboration broken down by the age, research career stage and highest level of qualification of the survey respondents, together with the country where the highest qualification was obtained. All shaded items represent the most selected collaborating partners by the relevant demographic category of respondents.

Table 10.5: Research collaboration with five regions, by demographics of survey respondents

Demographics	Zimbabwe only	Zimbabwe and RoA	Zimbabwe and RoW	Zimbabwe, RoA and RoW	Outside Zimbabwe only
	%	%	%	%	%
Gender					
Female (n=54)	19%	9%	9%	59%	4%
Male (n=161)	32%	26%	6%	30%	6%
Age					
≤40 (n=94)	24%	30%	7%	31%	6%
41-50 (n=62)	27%	21%	7%	44%	2%
51-60 (n=31)	42%	3%	7%	45%	3%
Over 60 (n=8)	13%	0%	0%	75%	13%
Highest academic qualification					
Master's or equivalent (=107)	40%	22%	8%	26%	4%
PhD or equivalent (n=102)	14%	23%	7%	50%	7%
Research career stage					
First stage researcher (n=99)	41%	25%	5%	23%	5%
Recognised researcher (n=41)	15%	27%	7%	44%	7%
Established researcher (n=43)	16%	23%	9%	47%	5%
Leading researcher (n=31)	19%	3%	10%	65%	3%
Country where highest qualification was obtained					
Zimbabwe (n=96)	46%	20%	8%	25%	1%
South Africa (n=55)	13%	36%	2%	38%	11%
Rest of Africa (n=8)	50%	13%	0%	38%	0%
United Kingdom (n=13)	0%	0%	8%	84%	8%
Rest of Europe (n=24)	13%	17%	8%	63%	0%
US (n=5)	0%	0%	20%	60%	20%
Rest of world (n=5)	20%	0%	40%	20%	20%

Note: Percentages add to 100% in the rows.

Based on Table 10.5, it is observed that the most selected collaborating partners of female researchers were individuals from RoA and the RoW (59%). Male researchers indicated that they collaborated more with individuals from Zimbabwe only (32%). Although it might have been assumed that women would collaborate more with individuals from the country (as shown by Beaudry et al. (2018), that male researchers are more mobile than female researchers), these results prove otherwise. A reason for this 'anomaly' could be that these female respondents might have obtained their highest qualification from countries outside of Zimbabwe. It has generally been argued that when researchers study abroad, they tend to maintain connections with their research teams even after returning to their home countries. With this factor in mind, a cross tabulation of respondents' gender and the country where they obtained their highest qualification was performed. The results are presented in Table 10.6. The table shows that 35 (60%) female researchers obtained their highest qualification from outside of Zimbabwe. This could explain why 32 (54%) reported that they collaborated with individuals in ZW, RoA and the RoW.

Table 10.6: Countries where survey respondents obtained highest level of qualifications

	Countries in Africa			Countries in Europe		Countries in rest of world	
	Zimbabwe	South Africa	Rest of Africa	United Kingdom	Rest of Europe	United States	Rest of world
	%	%	%	%	%	%	%
Female (n=58)	40%	25%	5%	10%	17%	0%	2%
Male (n=170)	50%	28%	3%	4%	9%	3%	3%

Note: Percentages add to 100% in the rows.

The reader is referred to Table 10.5 above. It can be observed in the table that the most selected collaborating partners of Zimbabwean researchers with a master's degree were individuals in Zimbabwe (40%). The table shows that researchers who obtained their highest qualification in South Africa collaborated more with ZW, RoA and RoW (21 or 38%). The majority of those who obtained their highest qualification in the UK, rest of Europe and the US reported that they collaborated with individuals in ZW, RoA and RoW (11 or 85%, 15 or 60%, and 3 or 60%, respectively). Fifty-one researchers (or 50%) with a PhD or equivalent collaborated with individuals in ZW, RoA and RoW. The latter are recognised, established and leading researchers. Most researchers who obtained their highest qualification in Zimbabwe only collaborated with individuals in Zimbabwe (44 or 46%).

10.5 Reasons for research collaboration

The survey respondents were asked, in an open-ended question, to state the single most important reason for engaging in research collaboration. A total of 225 (87%), out of a total of 259, responded to this question. The responses in SPSS were exported to Excel for thematic coding. Responses were classified into two broad themes; namely, instrumental versus intrinsic factors. Instrumental factors relate to resource-based motivations such as access to resources and special equipment, while intrinsic factors refer to individual choices and preferences such as knowledge-based motivations, including access to diversified skills and expertise, boosting productivity, and personal gains (Sargent & Waters, 2004). These factors are elaborated on in the sections that follow.

10.5.1 Intrinsic reasons for research collaboration

The most cited reasons for engaging in collaborative research fell under intrinsic factors. These factors were broken down into three categories: (i) access to knowledge, skills and expertise, (ii) increased research performance, and (iii) personal gains.

Most of the reasons for engaging in collaboration had to do with gaining knowledge or skills, gaining new expertise, or gaining access to research methods. All these knowledge-based factors were given the label '**access to knowledge, skills and expertise**'. Out of a total of 225, 143 (63%) responses fall under this category. However, the responses varied and were not clearly articulated. Some respondents cited only one of the aforementioned reasons while others cited them all. One respondent had this to say about gaining complementary skills and knowledge: *"We complement each other's research knowledge and skills. Some may be stronger in qualitative and others quantitative approaches. Collaboration, thus, gives us confidence to take up any type of research and be assured of success."*

Expertise in research methodology and data analysis also emerged as common drivers for engaging in collaboration. For instance, one respondent said the main reason was: *"to share different expertise such as methodology construction, data analysis tools, literature review."* Another said the reason for collaboration was*: "to share tacit knowledge on research, especially on methodology."*

Typical responses classified in the category '**increased research performance**' were to produce more publications, to share research roles, to improve the quality of research, and to facilitate the cross-fertilisation of ideas. Respondents regarded the production of articles as strongly dependent on collaboration. For instance, commenting on increased publications, one respondent said: "*I engaged in collaboration to quickly produce an article and to also produce something concrete."* Other responses implied that the quality of research was improved when more people worked together. For example, one said their reason for collaboration was: *"to enhance quality of the research output and to come out with impactful research that transforms the society."* Obtaining cross-fertilisation of ideas was also commonly highlighted as a reason for research collaboration, as stated by one respondent who said the reason for collaboration was: "*to enable cross pollination of ideas and harness from the research strengths of various participants."*

Examples of '**personal gains**' mentioned by respondents included building individual reputations, establishing research networks, and enabling viable career paths. Respondents highlighted gains such as learning from others and gaining skills in research from experienced colleagues. A response that encapsulates all issues that have to do with personal gains was: *"I engage in collaboration to learn from others, I am still inexperienced, collaboration helps me to leverage the skills of more experienced team members."*

10.5.2 Instrumental reasons for research collaboration

Instrumental factors for engaging in research collaboration were not cited as frequently as intrinsic factors. One reason for being cited less could be that instrumental reasons for research collaboration are related to knowledge production factors. These are simply the enablers of research. The two most common reasons falling in this category were (1) access to resources and equipment, and (2) access to funding. Respondents stated that they engaged especially in international research collaboration because of "*lack of funding in the country."* Others said their reasons for engaging in collaboration were "*to gain access to resources and equipment."* For instance, one said: "*I engage in collaborative research because of lack of facilities and proper resources locally*" while another revealed that their reason was *"to make it easy to access certain pieces of equipment."*

The study found that researchers in Zimbabwe had various reasons for engaging in research collaboration. Although themes were assigned to responses, it is important to note that these reasons are interrelated and cannot be studied in isolation of one another. What follows in the next section is a discussion of the choices considered important by researchers when selecting collaborators.

10.6 Aspects considered in selection of research collaborators

Respondents were asked to indicate, using a 4-point rating scale, how important each of 13 collaborator aspects was in their choice of a collaborator (1='not at all important'; 2='slightly important'; 3='moderately important'; 4='very important'). The frequency distribution of each variable is presented in Table 10.7. Having unique skills/expertise (86%) and complementary skills/knowledge (74%), as well as having strong work ethics (74%), were the three most important aspects considered when choosing collaborators as they received the largest shares of 'very important' responses. Being of the same sex was least important in the choice of collaborators (rated by 92% as 'not at all important'). In a follow-up question, respondents were asked to indicate what unique skills/expertise they considered important. The three most selected skills/expertise, in order of importance, were creative ideas (72%), article writing skills (68%), and statistical data analysis skills (64%).

Table 10.7: Aspects considered by survey respondents when selecting research collaborators

Collaborator aspects	Very important	Moderately important	Slightly important	Not at all important
	%	%	%	%
Collaborator has unique skills/expertise (n=231)	86.1%	12.1%	1.7%	0.0%
Collaborator has skills/knowledge that complement my own (n=233)	74.2%	24.0%	1.7%	0.0%
Collaborator has strong work ethics (n=228)	73.7%	22.4%	3.5%	0.4%
Collaborator has a good research reputation (n=230)	66.1%	26.5%	6.5%	0.9%
Collaborator gives credit where it is due (n=230)	58.3%	27.8%	10.0%	3.9%
Collaborator has access to special data (n=231)	40.7%	40.7%	14.7%	3.9%
Collaborator has access to special equipment (n=231)	39.4%	35.1%	16.0%	9.5%
Collaborator has access to funds (n=232)	36.6%	34.1%	19.0%	10.3%
Collaborator has the right profile or networks to attract funding (n=230)	37.0%	40.4%	16.5%	6.1%
Collaborator speaks my language (n=231)	5.2%	9.1%	16.5%	69.3%
Collaborator and I have the same nationality (n=231)	2.6%	6.9%	13.9%	76.6%
Collaborator and I are of the same sex (n=231)	0.4%	0.4%	6.9%	92.2%

Note: Percentages add to 100% in the rows.

A factor analysis, specifically a Principal Component Analysis (PCA), was performed on the 13 variables. A PCA typically takes a set of variables and reduces it into smaller sets of components (Pallant, 2016). The new components are then treated as new variables that can be measured. An analysis of the 13 variables, using orthogonal varimax rotation, yielded a Kaiser-Meyer-Olkin (KMO) value of 0.684, exceeding the recommended value of 0.6 (Kaiser, 1974, cited by Pallant, 2016). The Bartlett's test of sphericity also reached statistical significance, indicating that the sample size was adequate to yield distinct and reliable components. Only factors with an eigenvalue of less than one were retained, and all component loadings greater than 0.5 were regarded as both practically and statistically significantly loadings.

The resulting rotated component matrix grouped the 13 variables into four components, which together explained 62% of the variance in the original variable set. Table 10.8 shows the components and their loadings. All statistically and practically significant loading of greater than 0.5 are shaded. Labels were assigned to each of the four extracted components. The component labels included the following:

- The first component was labelled as **'demographic homophily'**. Demographic homophily refers to similarities between people's backgrounds. In this case, all items that had to do with age, gender, language and nationality grouped together in the PCA solution.
- Three items which pertained to resources and funding constituted the second component, which was labelled as **'access to resources'**.
- Two items that pertained to skills/expertise and knowledge constituted the third component, labelled as **'skills and expertise'**.
- The fourth component involved items that had to do with the collaborator's work ethics and good research reputation. These items were assigned the label of **'good work ethics'**.

Table 10.8: Aspects considered by survey respondents when selecting research collaborators: Extracted components and their loadings per item, based on a PCA performed on 13 variables

Collaborator aspects	**Component solution (62% variance explained)**			
	Component 1	**Component 2**	**Component 3**	**Component 4**
Label assigned to component 1: Demographic homophily				
Collaborator and I are similar in age	0.850	0.061	-0.021	-0.004
Collaborator and I are of the same sex	0.831	0.067	-0.017	0.001
Collaborator and I are the same nationality	0.745	0.078	0.045	0.064
Collaborator speaks my language	0.704	-0.051	0.088	-0.034
Label assigned to component 2: Access to resources				
Collaborator has access to funds	-0.010	0.869	0.109	-0.050
Collaborator has the right profile or networks to attract funding	0.108	0.768	0.299	-0.062
Collaborator has access to special equipment	0.043	0.738	0.008	0.247
Collaborator has access to special data	0.043	0.595	-0.115	0.432
Label assigned to component 3: Work ethics and reputation				
Collaborator has strong work ethics	-0.042	-0.060	0.733	0.223
Collaborator gives credit where it is due	0.164	0.095	0.727	0.103
Collaborator has a good research reputation	-0.026	0.203	0.708	0.051
Label assigned to component 4: Unique and complementary skills				
Collaborator has skills/knowledge that complement my own	0.061	0.112	0.175	0.759
Collaborator has unique skills/expertise	-0.051	0.061	0.187	0.743

A series of reliability tests were performed to determine the internal consistency of the four extracted components. Table 10.9 shows the test results. The first was Cronbach's alpha coefficient. The results showed that one of the four components had a score markedly less than 0.7 (component 4; 0.49), which falls below the recommended Cronbach alpha of a scale (>0.7), as stated by DeVellis (2012). Only two components thus fully met this criterion with a third approaching this criterion. Following Cronbach's alpha, mean inter-item correlations for the components were also calculated. Briggs and Cheek (1986) proposed an optimal range for the inter-item correlation of 0.2 to 0.4. Based on the results in Table 10.9, it is seen that the inter-item correlations of the four components ranged from 0.33 to 0.48, with the two components failing the Cronbach alpha criterion, falling in the optimal range. A third test, based on the Spearman Crown formula, was also performed. The reason was that internal consistency measurements (like Cronbach's alpha) are sensitive to the number of items used. Two components in the study comprised lesser items (three and two items, respectively), which contributes to the reduction in internal consistency. Hence, in this regard, the Spearman Brown formula was used to determine the size of coefficients if all components would consist of four items, which is the number associated with the component with the largest number of items. The Spearman Brown formula predicts the effect of lengthening a measure on the reliability of that measure. In this case, components 3 and 4 were theoretically extended to include four items each. After applying the formula, the scores of the components were 0.68 and 0.61, respectively, should both of these components theoretically be composed of four items each. Especially for component 4, the theoretical adjustment for the small number of original items result in the component's alpha coefficient being significantly adjusted upwards.

Table 10.9: Average inter-item correlations, Cronbach's alpha coefficient and Spearman Brown formula for four extracted components

Components	Number of items	Average inter-item correlations	Cronbach's alpha	Spearman Brown formula (for four items)
C1: Demographic homophily	4	0.48	0.71	0.71
C2: Access to resources	4	0.45	0.77	0.77
C3: Work ethics and reputation	3	0.35	0.61	0.68
C4: Unique and complementary skills	2	0.33	0.49	0.61

After running reliability tests, total scores for each of the components were computed. Each component was reduced to a single and new variable in the SPSS dataset. Item responses were originally captured to range from 1 ('very important') to 5 ('not at all important'). These were rescored in the dataset, starting with zero as the lowest value. The new scores were 0 ('not at all important'), 1 ('slightly important'), 2 ('moderately important'), and 3 ('very important'). The total score for component 1 could therefore range from 0 (i.e. four items x 0) to 12 (i.e. four items x 3). A high total score for this component reflects an orientation towards stressing the importance of demographic homophily. The total score for component 2 was the same as that for component 1, as both had the same number of items (four). The total score for component 3 could range from 0 (i.e. three items x 0) to 9 (i.e. three items x 3). The scores for component 4 could range from 0 (i.e. two items x 0) to 6 (i.e. two items x 3), where a high score of 6 indicates the importance of unique and complementary skills. However, the components' maximum scores differed because of a difference in the number or items per component. The component scores were therefore standardised by converting all to a score out of 10, such that all component scores ranged from 0 to 10 (with 0 indicating the lowest level of importance and 10 reflecting the highest level importance). Descriptive statistics for the four components (henceforth referred to as factors) are presented in Table 10.10.

Table 10.10: Descriptive statistics for four factors considered by survey respondents in the selection of research collaborators

Statistics	Factors			
	Demographic homophily	**Access to resources**	**Work ethics and reputation**	**Unique and complementary skills**
Mean (out of 10)	0.9	6.8	8.4	9.2
Median (out of 10)	0.0	6.7	8.9	10.0
Mode (out of 10)	0.0	10.0	10.0	10.0
Standard deviation	1.5	2.4	1.9	1.3
Minimum score	0.0	0.0	1.1	3.3
Maximum score	10.0	10.0	10.0	10.0
Number of cases	232	234	232	234

The table shows that demographic homophily, with a mean score of 0.9 out of 10, was viewed as least important when choosing research collaborators. Demographic homophily consisted of aspects such as similar sex, same language, same age, and same nationality. Unique and complementary skills, with a mean score of 9.2 out of 10, was considered the most important. The minimum score of unique and complementary skills was 3.3, the 'highest' compared to the other three components. Figure 10.6 visualises, in order of importance, the relative importance of the four factors (based on their mean scores in Table 10.10) in the selection of research collaborators.

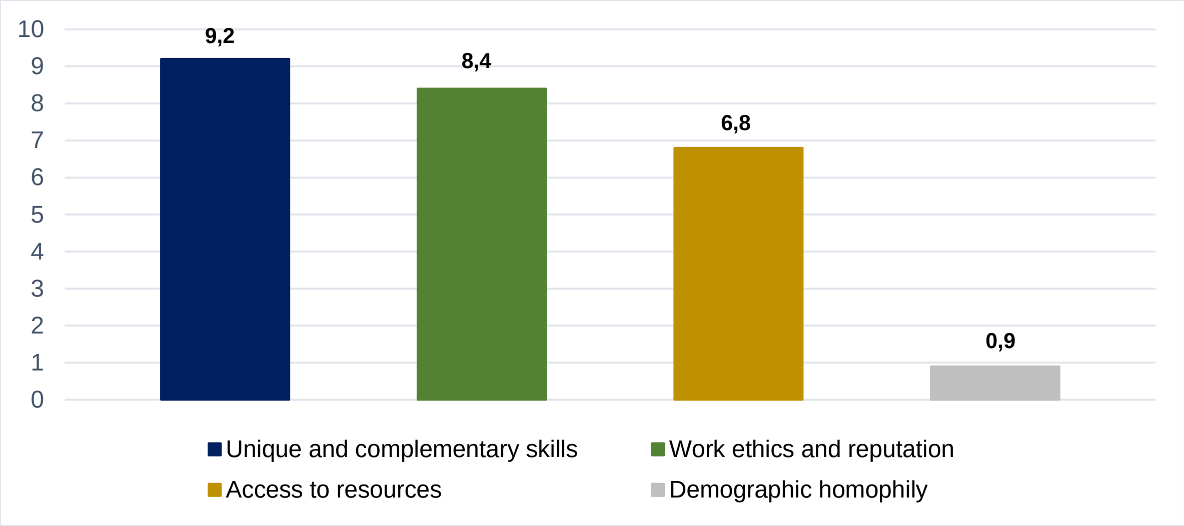

Figure 10.6: Relative importance of four factors considered by survey respondents in the selection of research collaborators (mean scores out of 10)

Each of the four factors created was treated as a new variable in the dataset, and was used to explore correlations with other variables in the dataset, namely geographic region and research career stage.

To measure how choices of collaborators differ according to geographic region, the mean factor scores were calculated for each of the five regions. A one-way ANOVA of variance (F-test) was conducted to determine whether the mean factor scores differ significantly from each other. It is important to note, as stated by Pallant (2016), that if the significance value (p) is less than or equal to 0.05, a significant difference among the mean scores for a particular factor can be observed. In this case, Table 10.11 shows that the significance value for each of the factors was greater than 0.05, indicating that there were no significant differences among the mean scores of the regions on each of the four factors.

Table 10.11: Mean scores for four factors considered by survey respondents in the selection of research collaborators, by region

Regions	Factors							
	Demographic homophily (out of 10)		Access to resources (out of 10)		Work ethics and reputation (out of 10)		Unique and complementary skills (out of 10)	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Zimbabwe only	69	1.3	69	6.8	69	8.4	69	9.3
Zimbabwe and RoA	49	0.9	49	7.1	49	8.3	49	9.3
Zimbabwe and RoW	17	0.5	17	6.7	17	8.9	17	9.2
Zimbabwe, RoA and RoW	85	0.6	86	6.9	84	8.5	85	9.2
Outside Zimbabwe only	12	0.5	13	5.2	13	8.0	14	8.3
Total	232	0.9	234	6.8	232	8.4	234	9.2
Significance	**F=2.062**		**F=1.835**		**F=0.441**		**F=1.764**	
	p= 0.087		**p=0.123**		**p=0.779**		**p=0.137**	

Table 10.12 shows the extent to which choices of collaborators (as measured by the four factors) varied across research career stages of respondents. The results show that no statistically significant differences were observed for three of the four factors (i.e. demographic homophily, access to resources, and work ethics and reputation), because the associated significance values (p) are greater than 0.05. A statistically significant difference ($p<0.05$) was observed for research career stage and the factor labelled as ‘unique and complementary skills’. However, despite reaching statistical significance, the mean differences in factor scores for the different research career stages were all at the upper end of the relevant factor. A post-hoc comparison using the Turkey HSD test showed that the mean score for first-stage researchers (9.5) differed significantly from that of leading researchers (8.8). This indicates that first-stage researchers, compared to leading researchers, consider unique and complementary skills as more important in the selection of research collaborators.

Table 10.12: Mean scores for four factors considered by survey respondents in the selection of research collaborators, by research career stage

Research career stages	Factors							
	Demographic homophily (out of 10)		Access to resources (out of 10)		Work ethics and reputation (out of 10)		Unique and complementary skills (out of 10)	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean
First-stage researcher	99	0.9	99	6.9	98	8.8	98	9.5
Recognised researcher	41	0.7	41	7.2	41	8.3	41	9.2
Established researcher	42	0.6	42	6.4	42	7.9	43	8.9
Leading researcher	30	1.3	31	6.5	30	8.7	31	8.8
Total	212	0.9	213	6.8	211	8.5	213	9.2
Significance	**F=1.375**		**F=1.031**		**F=2.574**		**F=3.486**	
	p= 0.252		**p=0.380**		**p=0.055**		**p=0.017**	

10.7 Challenges faced in research collaboration

Research collaboration is a socio-cognitive process and involves individuals who might have the same or conflicting values, rules and norms. Bozeman et al. (2016) state that collaboration is not always a positive experience; it can also lead to negative outcomes for researchers. Henceforth, this section provides information on the challenges faced by researchers in Zimbabwe during collaboration. Respondents in the survey were asked to rate 24 challenges on how serious a problem they were in research collaborations. The frequency descriptions are presented in Table 10.13.

Table 10.13: Challenges faced by researchers when engaging in collaboration

Challenges	Not applicable/ no problem at all	A minor problem	A moderate problem	A major problem
	%	%	%	%
Collaborators not delivering work when and/or as agreed (n=230)	12%	17%	23%	49%
Roles of collaborators not well defined (n=230)	19%	22%	26%	33%
Collaborators publishing the group's work without informing others (n=227)	53%	12%	8%	28%
Collaborators insisting on co-authorship without having made any contributions (n=229)	45%	15%	12%	28%
Collaborators using or distributing the research data without informing others (n=231)	53%	11%	9%	27%
Lack of recognition of technical staff in the collaboration (n=233)	33%	21%	19%	27%
Exploitation of junior researchers and/or students in the collaboration (n=231)	30%	29%	16%	26%
Activities of collaborators not well aligned (n=230)	19%	24%	33%	24%
Collaborators acting only in their own interests without considering others (n=229)	38%	22%	16%	24%
Lack of recognition of administrative staff in the collaboration (n=232)	34%	22%	20%	23%
Collaborators not being trustworthy (n=230)	51%	16%	11%	22%
Collaborators not sharing relevant information (n=227)	46%	16%	17%	21%
Lack of gender diversity in the collaboration (n=233)	51%	19%	18%	12%
Gender stereotyping in the collaboration (n=232)	66%	17%	10%	8%
Disputes about authorship (n=227)	54%	23%	15%	8%
Challenges related to leadership and control (n=225)	55%	22%	16%	8%
Being 'micro-managed' by others in the collaboration (n=188)	48%	17%	10%	8%
Diverse institutional cultures in the collaboration (n=230)	51%	26%	16%	7%
Collaborators in different career stages (n=229)	56%	22%	15%	7%
Large geographic distances between collaborators (n=228)	55%	21%	18%	7%
Diverse personality types of collaborators (n=229)	49%	33%	12%	7%
Diverse disciplinary cultures in the collaboration (n=228)	61%	21%	12%	6%
Diverse national cultures in the collaboration (n=228)	64%	22%	12%	2%

Note: Percentages add to 100% in the rows.

According to Table 10.13, a major challenge faced by researchers during collaboration was working with collaborators who fail to deliver work when or as agreed (49%). Another notable challenge had to do with defining the roles of the different collaborators (33%). Having diverse national cultures in the collaboration (2%), as well as diverse disciplinary cultures (6%), were not considered as major challenges.

As before, a PCA of the 24 challenges was performed to identify a smaller set of underlying dimensions. The purpose of a PCA, as previously explained in Section 10.6, is to group variables into sets of coalescing components. The components can then be treated as new variables that reflect on the challenges faced by researchers in Zimbabwe when engaging in research collaboration. Before the PCA could proceed, the original item response codes were first recoded in the SPSS database, such that the new scores were 0 ('not applicable/no problem at all', 1 ('a minor problem'), 2 ('a moderate problem'), and 3 ('a major problem'). Ultimately, three rounds of PCAs had to be performed because some of the PCA loadings were either non-significant or factorially complex. The first and second PCAs performed are presented in Table 10.14.

Table 10.14: Challenges faced by survey respondents when engaging in research collaboration: Extracted components and their loadings per item, based on PCAs performed on 24 variables (solution 1) and 21 variables (solution 2)

Challenges	Component solution 1 (69% variance explained)					Component solution 2 (71% variance explained)				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
Collaborators using or distributing the research data without informing others	.884	.095	.178	.162	.191	.880	.171	.093	.182	.200
Collaborators publishing the group's work without informing others	.867	.092	.179	.156	.175	.858	.173	.095	.183	.185
Breach of information security	.809	.024	.147	.288	.171	.806	.149	.017	.309	.164
Collaborators not being trustworthy	.805	.242	.160	.111	.142	.807	.176	.230	.135	.125
Collaborators not sharing relevant information	.761	.146	.226	.297	.217	.765	.227	.141	.309	.209
Collaborators insisting on co-authorship without having made any contributions	.753	.101	.289	.091	.267	.766	.266	.099	.084	.280
Collaborators acting only in their own interests without considering others in the group	.649	.286	.197	.314	.252	.654	.193	.296	.324	.253
Large geographic distances between collaborators	.107	.785	.055	-.023	-.088	.080	.058	.813	-.005	-.050
Diverse national cultures in the collaboration	.151	.682	.080	.066	.258	.137	.145	.651	.106	.225
Diverse institutional cultures in the collaboration	.230	.671	.152	.338	.011	.197	.145	.702	.355	.062
Diverse personality types of collaborators	.085	.625	.115	.208	.231	.087	.110	.649	.206	.257
Lack of gender diversity in the collaboration	.058	.560	.495	.096	.051	.067	.549	.501	.091	.016
Collaborators in different career stages	-.090	.496	.170	.385	.263					
Diverse disciplinary cultures in the collaboration	.441	.443	.254	.309	.061					
Gender stereotyping in the collaboration	.374	.412	.006	.179	.319					
Lack of recognition of technical staff in the collaboration	.283	.168	.854	.126	.155	.277	.854	.147	.140	.169
Lack of recognition of administrative staff in the collaboration	.256	.169	.838	.111	.142	.235	.839	.147	.134	.170
Exploitation of junior researchers and/or students in the collaboration	.395	.124	.698	.203	.192	.420	.698	.101	.189	.173
Challenges related to leadership	.275	.260	.128	.796	.107	.240	.148	.255	.821	.118
Disputes about authorship	.372	.114	.090	.769	.166	.360	.104	.097	.774	.158
Being 'micro-managed' by others in the collaboration	.341	.245	.217	.671	.155	.306	.229	.237	.697	.176
Activities of collaborators not well aligned	.277	.071	.149	.208	.807	.254	.146	.067	.224	.827
Roles of collaborators not well defined	.267	.183	.261	.225	.750	.256	.258	.167	.228	.770
Collaborators not delivering work when and/or as agreed	.339	.175	.088	.001	.701	.342	.077	.183	.000	.708

The stopping criterion for the first component solution was that the 'eigenvalue' should be greater than one. An orthogonal rotation (VARIMAX) was performed. The KMO value was 0.92 and the Bartlett's test of sphericity reached statistical significance, indicating that the PCA was statistically appropriate. The resulting rotated component matrix grouped the 24 variables into five components. However, three items (i.e. 'collaborators in different career stages', 'diverse disciplinary cultures in the collaboration', and 'gender stereotyping in the collaboration') had item loadings of less than 0.5. These three items therefore had to be excluded in further PCA analyses.

Subsequently, a new PCA with 21 items was performed (second component solution in Table 10.14). The solution grouped the 21 variables into five components, explaining 71% of the variability in items. However, it was decided to also exclude one more variable (i.e. 'lack of gender diversity in the collaboration') because of its significant loadings (>0.5) on more than one component, which made it factorially complex

Hence, a third and final PCA with 20 items was run. The results of this PCA are presented in Table 10.16. Again the solution grouped the 20 variables into five components, which explained 76% of the variance in the set of variables. The following descriptive labels were assigned to each component:

- The first component was labelled as **'dishonesty and untrustworthiness'**. This component included seven items that all had to do with collaborators being dishonest and not trustworthy. Two examples of items included in this component are 'collaborators using or distributing the research data without informing others' and 'collaborators not being trustworthy'.
- Three items dealing with issues of leadership and information security defined the second component. The component was labelled as **'issues of management and control'**.
- The third component was labelled **'lack of homophily'** as it comprised four items that had to do with collaborators' diverse institutional and national cultures and personality types.
- The fourth component comprised items that had to do with collaborators failing to recognise some team members who were not academics. This component was labelled **'disregard for research support staff'**.
- Three items labelled **'unclear demarcation of collaborator roles'** constitute the last component. Two items included in this component were 'activities of collaborators not well defined' and 'roles of collaborators not well defined'.

Table 10.15: Challenges faced by survey respondents when engaging in research collaboration: Extracted components and their loadings per item, based on a PCA performed on 20 variables (final component solution)

Challenges	Component solution 3 (76% variance explained)				
	C1	C2	C3	C4	C5
Label assigned to component 1: Dishonesty and untrustworthiness					
Collaborators using or distributing the research data without informing others	0.877	*	*	*	*
Collaborators publishing the group's work without informing others	0.853	*	*	*	*
Collaborators not being trustworthy	0.809	*	*	*	*
Being 'micro-managed' by others in the collaboration	0.802	*	*	*	*
Collaborators not sharing relevant information	0.763	*	*	*	*
Collaborators insisting on co-authorship without having made any contributions	0.760	*	*	*	*
Collaborators acting only in their own interests without considering others	0.650	*	*	*	*
Label assigned to component 2: Issues of management and control					
Challenges related to leadership and control	*	0.826	*	*	*
Disputes about authorship	*	0.777	*	*	*
Breach of information security	*	0.710	*	*	*
Label assigned to component 3: Lack of homophily					
Large geographic distances between collaborators	*	*	0.828	*	*
Diverse institutional cultures in the collaboration	*	*	0.731	*	*
Diverse personality types of collaborators	*	*	0.652	*	*
Diverse national cultures in the collaboration	*	*	0.645	*	*
Label assigned to component 4: Disregard for research support staff					
Lack of recognition of technical staff in the collaboration	*	*	*	0.866	*
Lack of recognition of administrative staff in the collaboration	*	*	*	0.866	*
Exploitation of junior researchers and/or students in the collaboration	*	*	*	0.708	*
Label assigned to component 5: Unclear demarcation of collaborator roles					
Activities of collaborators not well aligned	*	*	*	*	0.824
Roles of collaborators not well defined	*	*	*	*	0.772
Collaborators not delivering work when and/or as agreed	*	*	*	*	0.710

A reliability test (Cronbach's alpha coefficient) was performed to determine the internal consistency of the five extracted components. The Cronbach alpha coefficients for the components are shown in Table 10.16. As can be seen, the Cronbach alpha values of the five components were all greater than 0.7, indicating good internal consistency.

Table 10.16: Cronbach's alpha coefficients for five extracted components

Components	Number of items	Cronbach's alpha
Dishonesty and untrustworthiness	7	0.945
Disregard for research support staff	3	0.891
Lack of homophily	4	0.764
Issues of management and control	3	0.822
Unclear demarcation of collaborator roles	3	0.855

Having conducted the reliability test, total scores for each component were computed in order to cast each component as a new and separate variable in the dataset. Since the item response codes ranged from 0 ('not applicable/no problem at all') to 3 ('a major problem'), the total score for component 1 could range from 0 (i.e. seven items x 0) to 21 (i.e. seven items x 3). A high score on this component reflects an orientation towards stressing how big a challenge dishonesty and untrustworthiness was in research collaboration. The total score for component 2 ranged from 0 (i.e. four items x 0) to 12 (i.e. four items x 3), while the total scores for components 3, 4 and 5 could each range from 0 (i.e. three items x 3) to 9 (i.e. three items x 3). Since the five components' maximum scores differed based on the number of items comprising each component, the component scores had to be standardised by converting all values to a score out of 10. All component scores thus ranged from 0 to 10, with 0 indicating a factor that was 'not applicable/no problem at all' and 10 a factor that was considered a major problem. Comparable descriptive statistics for the five components (referred to as factors from now on) are provided in Table 10.17.

Table 10.17: Descriptive statistics for five factors perceived as challenges in research collaboration by survey respondents

Statistics	Factors				
	Dishonesty and untrust-worthiness	Issues of management and control	Lack of homophily	Disregard for research support staff	Unclear demarcation of collaborator roles
Mean (out of 10)	3.7	2.7	2.3	4.5	6.0
Median (out of 10)	2.4	2.2	1.7	4.4	6.7
Mode (out of 10)	0.0	0.0	0.0	0.0	8.9
Standard deviation	3.6	3.0	2.3	3.6	3.1
Minimum score	0.0	0.0	0.0	0.0	0.0
Maximum score	10.0	10.0	9.2	10.0	10.0
Number of cases	231	230	231	233	231

Table 10.17 shows that unclear demarcation of collaborator roles, with a mean score of 6 out of 10, was considered a key problematic factor in research collaborations. This factor included aspects such as 'collaborators not delivering work when and/or as agreed', 'roles of

collaborators not well defined', and 'activities of collaborators not well aligned'. Lack of homophily (with items such as 'large geographic distances between collaborators', 'diverse institutional and national cultures', and 'diverse personality types of collaborators'), with a mean factor score of 2.3, was the least likely to be considered a challenge in collaboration. The implication is that the survey respondents were less likely to be affected by either the geographic distances or differences in national or institutional cultures of their collaborators.

Figure 10.7 visualises part of the results in Table 10.17 and shows, in order of importance, the position of the five factors as challenges experienced in research collaboration. As can be seen, the greatest challenge experienced by researchers was unclear demarcation of collaborator roles.

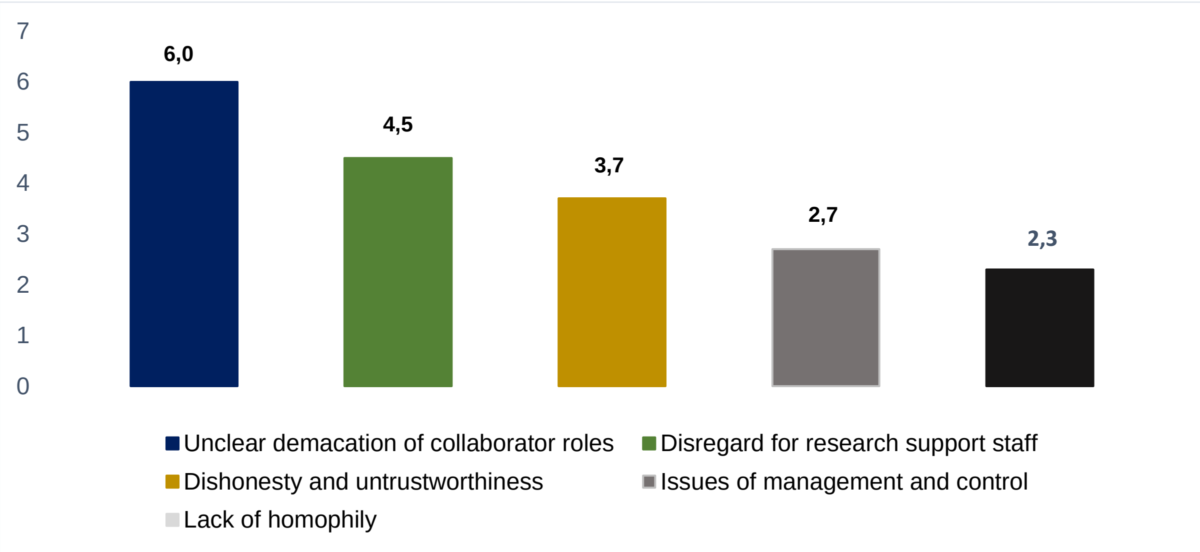

Figure 10.7: Relative importance of five factors perceived as challenges in research collaboration by survey respondents (mean scores out of 10)

Each factor was subsequently used in further analyses to determine whether the challenges in research collaboration differed according to the regions and research career stages of respondents. As a first step, mean factor scores were computed for each of the five regions. A one-way ANOVA was then performed to test for significant differences in mean scores. Table 10.18 shows the results. Significant differences ($p<0.05$) were observed for two of the five factors – namely, 'dishonesty and untrustworthiness' and 'unclear demarcation of collaborator roles' – which means that scores for these two factors differed significantly according to region.

Table 10.18: Mean scores for five factors perceived as challenges in research collaboration by survey respondents, by region

Regions	Factors									
	Dishonesty and untrust-worthiness		Issues of management and control		Lack of homophily		Disregard for research support staff		Unclear demarcation of collaborator roles	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Zimbabwe only	67	4.7	67	3.5	67	2.7	68	5.0	67	6.7
Zimbabwe and RoA	48	2.6	48	2.2	48	1.9	49	4.8	49	5.4
Zimbabwe and RoW	17	4.0	17	2.0	17	1.9	17	4.4	17	4.3
Zimbabwe, RoA and RoW	85	3.6	84	2.6	85	2.5	85	4.2	84	6.4
Outside Zimbabwe only	14	1.8	14	2.1	14	1.5	14	3.3	14	4.6
Total	231	3.7	230	2.7	231	2.3	233	4.5	231	6.0
Significance	**F=3.626**		**F=2.175**		**F=1.554**		**F=1.047**		**F=4.032**	
	p=0.007		**p=0.073**		**p=0.188**		**p=0.384**		**p=0.004**	

For the factor labelled as 'dishonesty and untrustworthiness', post-hoc comparisons using the Turkey HSD test were performed in order to determine the number and nature of the significant differences for this factor. Two significant differences were found. Firstly, the mean factor score for respondents collaborating within Zimbabwe only (4.7) was significantly higher than the mean score for respondents who collaborated in both Zimbabwe and the RoA (2.6). Secondly, the mean score for respondents collaborating within Zimbabwe only (4.7) was also significantly different from that for respondents collaborating outside of Zimbabwe only (1.8). Post-hoc comparisons using the Turkey HSD test were also performed for the factor labelled as 'unclear demarcation of collaborator roles'. One statistically significant difference was observed: the mean score for respondents collaborating within Zimbabwe only (6.7) was significantly higher than the corresponding score for respondents with collaborations both in Zimbabwe and the rest of the world outside of Africa (4.3).

Table 10.19 shows how the scores on the five factors differ according to the research career stages of the survey respondents. Mean scores of the components were calculated and a series of one-way ANOVAs performed.

Table 10.19: Mean scores for five factors perceived as challenges in research collaboration by survey respondents, by research career stage

Research career stages	Factors									
	Dishonesty and untrustworthiness		Issues of management and control		Lack of homophily		Disregard for research support staff		Unclear demarcation of collaborator roles	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
First-stage researcher	99	3.7	98	2.9	99	2.4	99	5.1	98	6.0
Recognised researcher	40	3.8	40	2.8	40	2.4	41	4.4	40	6.3
Established researcher	43	3.4	43	2.4	43	2.1	43	3.8	43	5.7
Leading researcher	30	4.3	30	2.6	30	2.6	30	4.4	30	6.0
Total	212	3.7	211	2.7	212	2.4	213	4.6	211	6.0
Significance	**F=0.371**		**F=0.398**		**F=0.288**		**F=1.376**		**F=0.237**	
	p=0.774		**p=0.754**		**p=0.834**		**p=0.251**		**p=0.871**	

As stated earlier, a significance value of less than 0.05 indicates statistical differences between the means factor scores (Pallant, 2016). Table 10.19 shows that the significance value for each of the components was greater than 0.05, meaning there were no significant differences among the mean factor scores for the different research career stages. This indicates that regardless of research career stage, researchers in Zimbabwe view challenges faced during research collaboration the same.

10.8 Authorship disputes in research collaboration

Decision-making in collaboration is said to be complex and multifaceted and may include diverse consideration (Youtie & Bozeman, 2014). In some cases, collaborators may also clash and disputes may arise. In this regard, the study sought to find examples, if any, of authorship disputes faced by researchers in Zimbabwe. The survey therefore asked the respondents to indicate if they had experienced any authorship disputes. Of the 223 respondents involved in article co-authorship, a quarter (25%) indicated that they had experienced such disputes.

Disputes in authorship are potentially related to a number of variables. Some of these include: (i) the size of research groups, (ii) the location of researchers, (iii) the scientific fields involved, and (iv) the research career stages of individuals. The following sections examine how the aforementioned variables relate to authorship disputes in Zimbabwe. Respondents were asked to indicate the average size of the research groups they worked in. Table 10.20 shows the response distribution for the 213 respondents who answered the question. It also shows the percentage of respondents in each size category who experienced an authorship dispute.

Table 10.20: Average size of research groups and the percentage of respondents in each size category who faced authorship disputes

Average size of research groups	Number of respondents	% of respondents with authorship disputes	
		Count	%
2 individuals	19	3	16%
3 individuals	56	10	18%
4 individuals	57	17	30%
5 individuals	27	3	11%
More than 6 individuals	54	21	39%
Total	**213**	**54**	**25%**

The table shows that the highest numbers of authorship disputes were faced by those in research groups with more than six individuals. It shows that out of a total of 54 respondents who worked in research groups with more than six individuals, 39% experienced disputes during co-authorship. The table also shows that out of a total of 57 researchers who worked in research groups with four individuals, 30% confirmed that they had experienced authorship disputes.

Having identified the size of research groups of researchers in Zimbabwe, the next step was to establish the percentages of those who faced disputes based on the geographic region of collaborators. To facilitate interpretation, Tables 10.21 and 10.22 need to be viewed together. Table 10.21 shows that the highest percentages of respondents who reported authorship disputes were confirmed by those who collaborate with others from the rest of Africa and the rest of the world (36%), and from those who said they collaborate with others from outside Zimbabwe only (36%). Out of the total percentage of those who collaborate only with individuals from outside of Zimbabwe, 80% (or four respondents – see Table 10.21) reported that they were in research groups with six or more individuals. Similarly, out of 80 respondents who collaborated with individuals across the globe (i.e. Zimbabwe, rest of Africa, and rest of world) 36% (or 29 respondents) faced authorship disputes at some point in time. Of these 29, 48% said they worked in research groups with six or more people (Table 10.21). These results seem to indicate that geographic distance, together with team size, have the potential to contribute to authorship disputes. In other words, the further researchers are from one another, and the larger the team, the greater the probability of a dispute.

Table 10.21: Percentage of survey respondents who experienced authorship disputes when collaborating with individuals in five regions

Collaborating regions	Number of respondents	% of respondents with authorship disputes	
		Count	%
Zimbabwe only	62	10	16%
Zimbabwe and RoA	42	9	21%
Zimbabwe and RoW	16	1	6%
Zimbabwe, RoA and RoW	80	29	36%
Outside Zimbabwe only	14	5	36%
Total	**214**	**54**	**25%**

Table 10.22: Distribution of research group size, per collaborating region, for survey respondents who experienced authorship disputes

Collaborating regions	Size of research group									
	2 individuals		3 individuals		4 individuals		5 individuals		6 or more individuals	
	Count	%	Count	%	Count	%	Count	%	Count	%
Zimbabwe only (n=10)	0	0%	4	40%	4	40%	1	10%	1	10%
Zimbabwe and RoA (n=9)	3	33%	2	22%	3	33%	0	0%	1	11%
Zimbabwe and RoW (n=1)	0	0%	0	0%	0	0%	0	0%	1	100%
Zimbabwe, RoA and RoW (n=29)	0	0%	4	14%	9	31%	2	7%	14	48%
Outside Zimbabwe only (n=5)	0	0%	0	0%	1	20%	0	0%	4	80%

Note: Percentages add to 100% in the rows.

In general, it can be argued that collaboration experiences might vary according to field, with some fields more likely to face authorship disputes than others. For instance, Marusic et al. (2011) reported that two thirds of studies of unethical authorship practices were in the fields of the biomedical and health sciences. In this regard, this study sought to find out how authorship disputes varied according to the field affiliations of the survey respondents. A total of 203 responses were analysed. Table 10.22 shows the total number of those who responded in each field and those who confirmed cases of author disputes. Authorship disputes were most prevalent in the health sciences: 39% of 49 respondents reported disputes (Table 10.23). Of those with disputes, 71% were in research groups with six or more individuals (Table 10.24).

Table 10.23: Percentage of survey respondents in five fields who experienced authorship disputes

Fields of survey respondents	Number of respondents	% of respondents with authorship disputes	
		Count	%
Agricultural sciences	24	7	29%
Health sciences	46	18	39%
Humanities	7	1	14%
Social sciences	76	13	17%
Natural sciences	50	12	24%
Total	**203**	**51**	**25%**

Table 10.24: Distribution of research group size, by field of survey respondents who experienced authorship disputes

Fields of respondents	Size of research group									
	2 individuals		3 individuals		4 individuals		5 individuals		6 or more individuals	
	Count	%	Count	%	Count	%	Count	%	Count	%
Agricultural sciences (n=7)	0	0%	2	29%	3	43%	0	0%	2	29%
Health sciences (n=17)	0	0%	1	6%	3	18%	1	6%	12	71%
Humanities (n=1)	0	0%	0	0%	0	0%	0	0%	1	100%
Social sciences (n=13)	3	23%	3	23%	4	31%	0	0%	3	23%
Natural sciences (n=12)	0	0%	3	25%	6	50%	1	8%	2	17%

Note: Percentages add to 100% in the rows.

Authorship disputes are also likely to vary across the research career stages of individuals. For instance, it is common for young scientists to fall prey to senior scientists who misuse their seniority to gain undesired authorship credits (Tsai et al., 2016). Therefore, the study sought to examine how instances of authorship disputes varied according to the career stage of researchers in Zimbabwe. Table 10.25 shows that out of 27 survey respondents who classified themselves as a ‘leading researcher’, 41% (11 respondents) reported that they had experienced such disputes. All of these leading researchers were involved in research teams comprising three or more individuals, as can be seen in Table 10.26. Although it might have been assumed that first-stage researchers would face more authorship disputes as compared to established and leading researchers, the results prove otherwise. The reason is perhaps self-explanatory, as first-stage researchers tend to collaborate more within Zimbabwe (see again Table 10.5), and most disputes are experienced by researchers who collaborate with individuals outside of Zimbabwe (see again Table 10.22).

Table 10.25: Percentage of survey respondents in five career stages who experienced authorship disputes

Research career stages of respondents	Number of respondents	% of respondents with authorship disputes	
		Count	%
First-stage researcher	102	17	17%
Recognised researcher	40	14	35%
Established researcher	38	9	24%
Leading researcher	27	11	41%
Total	**207**	**51**	**25%**

Table 10.26: Distribution of research group size, by career stage of survey respondents who experienced authorship disputes

Research career stages of respondents	Size of research group									
	2 individuals		3 individuals		4 individuals		5 individuals		6 or more individuals	
	Count	%	Count	%	Count	%	Count	%	Count	%
First-stage researcher (n=16)	2	13%	3	19%	7	44%	0	0%	4	25%
Recognised researcher (n=14)	1	7%	0	0%	3	21%	1	7%	9	64%
Established researcher (n=19)	0	0%	2	22%	4	44%	0	0%	3	33%
Leading researcher (n=11)	0	0%	4	36%	2	18%	1	9%	4	36%

Note: Percentages add to 100% in the rows.

10.8.1 Nature of authorship disputes

The study also enquired about the nature of authorship disputes experienced. The 55 respondents who indicated that they had experienced an authorship dispute were asked to select from a list of four items what their dispute was about. Figure 10.8 presents the results.

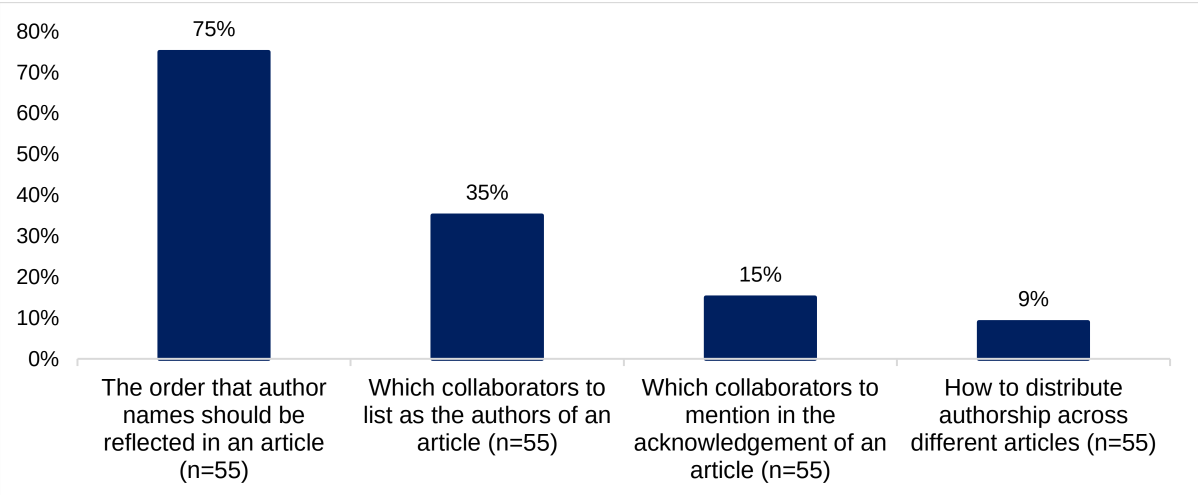

Figure 10.8: Nature of authorship disputes experienced

The most frequently selected item was the order in which author names should be reflected in articles (75%), followed by which collaborators to list as authors in an article (35%), and which collaborators to mention in the acknowledgement of an article (15%).

Asked whether these disputes were ever resolved, 34 of the 55 respondents (62%) said yes, while 15 (27%) said they failed to resolve disputes, and six (11%) said they were uncertain as to whether the disputes had been resolved.

Information on how these disputes were resolved was sought. Through an open-ended question, respondents were asked to explain how they resolved co-authorship disputes. Those who indicated that they had failed to settle issues were also asked to explain why they could not resolve matters. Responses were imported into an Excel data sheet for thematic analyses. Thirty-seven responses were received. Of the 37, 30 reported having managed to resolve disputes while seven indicated that they had failed to do so. The most common responses provided by those who managed to come up with resolutions were that disputes had been resolved (i) after considering individual contributions, (ii) after discussions and consensus, and (iii) through intervention by the principal investigator/mentor/funder. Themes identified among those who reported that they had failed to settle matters were: (i) keeping quiet about the matter, (ii) realising it was too late to resolve the matter, and (iii) withdrawal of name from the article. These responses are explained in greater detail below.

Twelve respondents reported that they resolved authorship disputes after considering the percentage contributions of the individual authors in articles. It is not unusual that during article writing, some members within research groups contribute more than others. Hence, respondents pointed out that the name of the author who contributed the most was considered to be the first author. For example, one respondent said they were able to resolve their disputes by *"explaining the contribution of each member to the manuscript and using that contribution to determine the order of authors on the manuscript."*

The second most highlighted way of resolving disputes was through discussions and reaching consensus. One respondent, who felt that he/she did not work to his/her full potential on an article, had this to say: "*… I decided to write* [another] *article on my own and then I made the collaborator the main author* [of the article in dispute]*."* Some discussions were said to be about the absolute maximum number of authors to be included in articles. For instance, one said:

> *"we resolved our matter through continued discussion and explanation about the restricted number of authors that could be listed and agreement to [only] include those that had contributed the most data, if that number was exceeded."*

Some disputes were resolved after the intervention of either a project leader, mentor or funder. While one respondent indicated that a dispute had been resolved through the intervention of a funder, the remaining respondents revealed that either their supervisors or mentors had to pitch in to solve matters. As one respondent noted:

> "[The] *mentor relationship ended up being used as the criterion for making decisions on matters to do with order of editors to the multi- and inter-disciplinary book we were working on."*

While some disputes were resolved, others were left unresolved. Matters became worse, especially when someone with a senior position was involved. For instance, one respondent reported: "*one of the people who insisted on being the main author had a senior position in the department, so I decided to keep quiet*." For some, they felt it was too late for them to resolve issues. For instance, one respondent only found out when the article to which he/she had contributed had already been published that his/her name had been excluded. Another respondent stated that he/she withdrew his/her name from the article altogether and vowed not to collaborate again with the "*difficult researchers."*

10.8.2 Ways used to establish article co-authorships

The survey sought to understand how co-authorship of articles was commonly established. Respondents were asked to select from four options how, in their experience, co-authorship had been established. The results are present in Figure 10.9, in order of importance. It is shown that co-authorships were either informally negotiated among members of research groups on a case-to-case basis, or by following common practices in research fields.

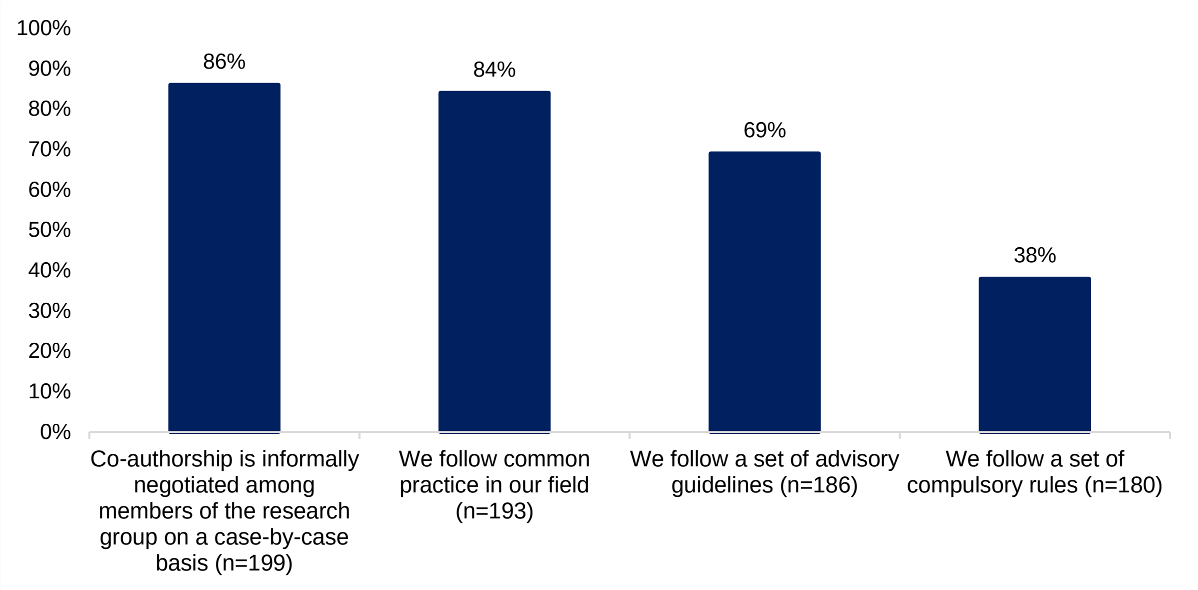

Figure 10.9: Ways in which co-authorship of articles are most commonly established

The respondents involved in co-authorship were also asked to select from a list of research stages the most appropriate stages to discuss issues of co-authorship of articles. Table 10.27 shows the results.

Table 10.27: Most appropriate stages to discuss issues of co-authorship of articles (n=227)

Stages	Count	%
During conceptualisation of the research	178	78%
During proposal writing	95	42%
During finalisation of a research contract/agreement	52	23%
During development of a data management plan	35	15%
During data collection	35	15%
During data analysis	38	17%
During article writing	78	34%
During submission of an article to a journal	32	14%

The most appropriate stage to discuss issues of co-authorship, as seen in Table 10.27, was during conceptualisation of the research. As stated by one respondent: *"… it is better to discuss these issues as early as possible in the research process to avoid disagreements*." Discussing co-authorship issues during proposal writing was also considered important, as stated by one respondent: *"… this is important in that the foundation is well set out as detailed in the proposal plan. Data gathering is made easy and technical skills in analysis are utilised."*

Others felt it was ideal to discuss issues of co-authorship during article writing. One explained:

"… research is an ongoing activity that needs continuous engagement. You cannot talk about co-authorship only at the beginning or at the end. Lest someone just comes in when it is time to publish and benefit where they did not contribute."

While some felt it was important to discuss authorship issues at all stages, one response was that such discussions had to take place during the submission of an article to a journal. The reasoning was:

"At the conceptualisation and proposal writing potential co-authors can agree on the ethics and mode of operation. This will help in clarifying issues of considerations to be made for one to become a co-author. However, as the research progresses, some researchers may become committed elsewhere and thus may not contribute as much as would have been envisaged at the conceptualisation and proposal writing stage thereby warranting changes to author sequencing on the manuscript. Thus, at the submission stage everyone will be having an appreciation of the contribution of each author."

10.9 Data ownership and data sharing in research

The final focus of this chapter is on data ownership and data sharing. Data sharing can be a controversial matter in the research process. While some researchers are sceptical about sharing their raw data, others are usually concerned about privacy and confidentiality issues that may arise as a result of sharing research data publicly. The study sought to solicit information about data ownership and the data sharing practices of researchers in Zimbabwe. Respondents were asked to select from a list of five items the data ownership and sharing practices they had been involved in during the previous five years. The responses are presented in Table 10.28.

Table 10.28: Data use and data sharing practices of survey respondents

Practices	Count	%
Shared your data with one or more Zimbabwean researchers	188	78%
Shared your data with one or more international researchers	154	65%
Shared your data on a repository	121	54%
Used a research assistant or junior researcher to collect data for your own research	108	47%
Used a student to collect data for your own research	102	43%
Collected data for the research of a Zimbabwean researcher	92	40%
Collected data for the research of an international researcher	82	36%
Used data that belongs to someone else	64	28%

As illustrated in the table, data was shared with both fellow Zimbabweans (78% of respondents) and international researchers (65%). Data was also shared in repositories (54%). However, using data that belonged to other researchers was uncommon. This might be the case because data use practices tend to be field-specific, a hypothesis that is explored in Table 10.29.

Table 10.29: Survey respondents who used data that belonged to someone else, by field

Fields	Number of respondents	% of respondents who used data that belong to someone else	
		Count	%
Agricultural sciences	22	10	45%
Health sciences	46	14	30%
Humanities	15	2	13%
Social sciences	84	15	18%
Natural sciences	52	21	40%
Total	219	62	28%

10.9.1 Nature of data ownership and data sharing disputes

The study also explored the nature of data ownership and sharing disputes. As a first step, those who reported that they had experienced such cases were identified. It emerged that out of 240 respondents, only 16 (7%) reported incidents of data ownership and sharing.

Respondents were asked to explain what the disputes were about and whether they had been resolved. It emerged that clashes centred around data ownership – that is, who had rights over the data or samples between, for example, the researchers who carried out the research and wrote articles, and the organisations from which data was collected. For instance one respondent had this to say:

> *"We had done some consultancy for a company and had agreed that we could use data for research. However, when we tried to publish a paper at the end of the project the company asked us to wait until they had used the results for applying for a research grant. This is despite including members of the company as co-authors in the publication. Up to now we have not published that paper."*

The respondent went on to say:

> *"… as this is data from commissioned work the onus of approving the submission lies with the company. However, we are still negotiating with the company to allow us to publish the manuscript."*

Another respondent narrated an incident whereby a student collected data from an organisation and, after collecting the data and writing an article, the organisation pressed for one of their staff members to be added as a co-author. To resolve the matter, the respondent reported: "*we decided to rework the article with their contribution, and we co-authored the article*." Another example related to data rights provided by a respondent was that a donor organisation wanted to have direct access to patent-level data and to further sample processing. The respondent went on to explain that: "*the donor won the argument and proceeded to perform further sample processing*."

Other disputes had to do with issues of dishonesty and untrustworthiness. An incident related to dishonesty was experienced by one respondent who revealed that: *"Data was provided with a verbal agreement but however, later the private land holder declined us to publish the data."* The respondent said they decided to retract the paper.

In another incident, a respondent who had their data published but was not acknowledged in the article, had this to say:

> *"One of the people in my department published a study which used my data and did not acknowledge the source of the data and I was not an author on the study. The supervisor was a younger member of staff – we had to have a discussion to explain that we were not happy about what was done and ask that it was not repeated. The person was apologetic, but the article had been published, nothing could be done. I have been more hesitant to share my data with anyone since this time and rather wary about this person. If what we saw as 'trust' was broken it is difficult to regain this."*

10.9.2 Ways used to establish data ownership

Respondents were presented with four items in order to indicate how, in their experience, data ownership had been established (Figure 10.10). As can be seen from the figure, all four items were popular choices among the respondents. However, the most selected item was following common practices in respective fields (85%), followed by following sets of advisory guidelines (77%). The least selected item was through following sets of compulsory rules (64%).

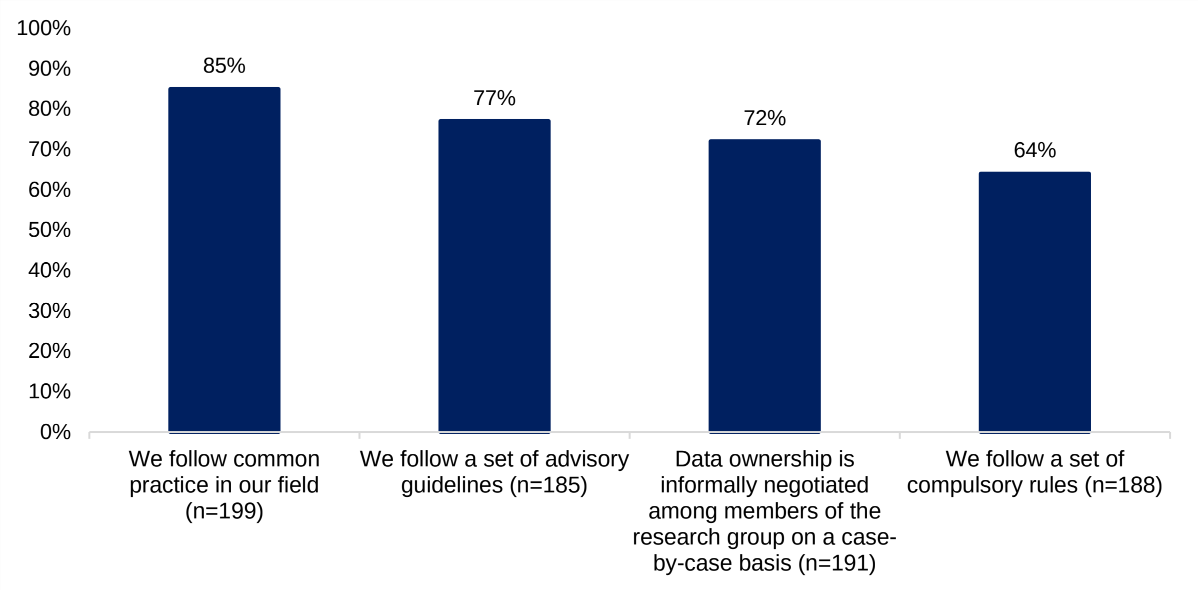

Figure 10.10: Ways in which data ownership are most commonly established

The study also sought to find out researchers' views on the most appropriate stages at which to discuss issues of data ownership. As can be seen in Table 10.30, the most frequently selected option of discussing data ownership was during the conceptualisation of research (80%), and during the proposal writing stage (40%). In other words, right at the project start.

Table 10.30: Frequency distribution of stages appropriate to discuss issues of data ownership

Stages	Count	%
During conceptualisation of the research	207	80%
During proposal writing	104	40%
During finalisation of a research contract/agreement	88	33%
During development of a data management plan	70	27%
During data collection	56	22%
During data analysis	35	14%
During feedback (of results) to the funder/contracting agency	29	11%
During preparations for data preservation	45	17%
Upon depositing of data in an institutional or subject data repository	41	16%
Upon leaving a research institution for employment elsewhere	28	11%

Respondents were asked, based on a 4-point rating scale, to indicate how big a challenge issues of data ownership are considered in their research field. The results are presented in Figure 10.11. Approximately 62% of the respondents said that issues of data ownership and sharing were either not a problem at all (35%) or a minor problem (27%) in their field.

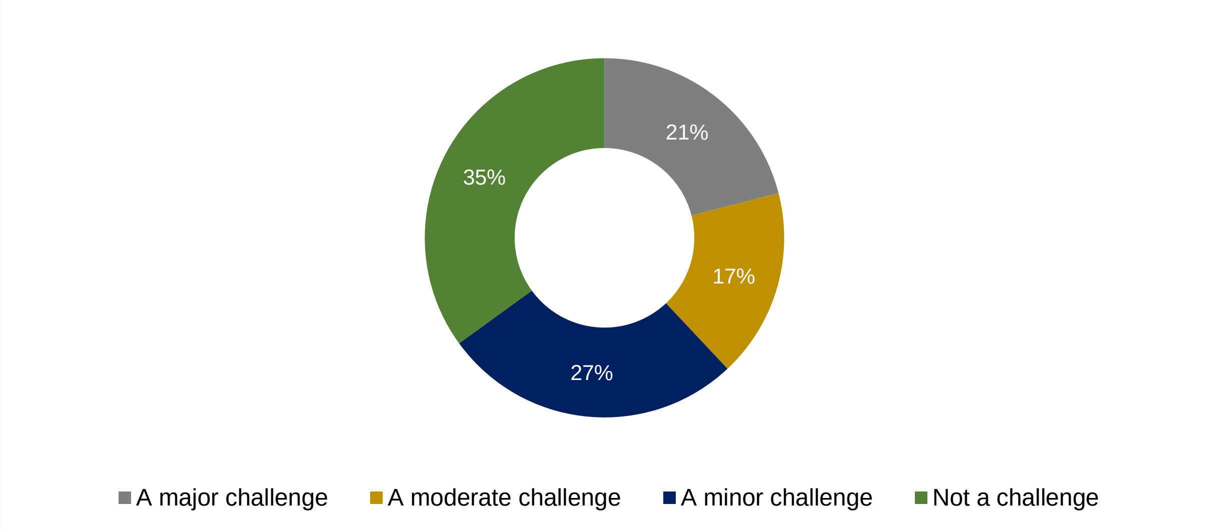

Figure 10.11: Respondents' views on the degree of challenge that data ownership and data sharing present in their research field (n=234)

It is generally agreed that issues of data ownership and data sharing vary across fields. Some fields are more likely than others to generate and use large data sets as part of their research processes. For instance, researchers in the natural or health sciences work with specimens, objects and protein structures, whereas those in the social sciences produce their data through interviews, questionnaires and observations, which might not be as problematic in terms of ownership and sharing. In this regard, the study sought to determine how challenges of data ownership and data sharing varied across fields. Table 10.31 provides a breakdown of responses according to the fields to which the respondents belonged. It is observed that data ownership was not considered to be a big challenge in any field, as between 27% and 42% of respondents selected the 'not a challenge' option. However, close to a quarter of respondents in the natural sciences (24%) and social sciences (23%) considered data ownership and data sharing in their field to be a major challenge.

Table 10.31: Respondents' views on the challenge that data ownership and data sharing present for them, by field

Fields of respondents	A major challenge		A moderate challenge		A minor challenge		Not a challenge	
	Count	%	Count	%	Count	%	Count	%
Agricultural sciences	3	13%	3	13%	8	33%	10	42%
Health sciences	10	21%	9	19%	14	29%	15	31%
Natural sciences	13	24%	12	22%	15	27%	15	27%
Social sciences	20	23%	15	17%	20	23%	34	38%
Humanities	2	14%	1	7%	7	50%	4	27%
Total	48	100%	40	100%	64	100%	78	100%

Note: Percentages add to 100% in the rows.

In a follow up question, researchers were asked to provide reasons for their responses as to why they had rated the issue of data ownership and sharing in a particular way. Many respondents who regarded data ownership as not a challenge said that this was because the roles of researchers and data owners were clearly defined before the research was undertaken. Others revealed that issues of data ownership were determined by institutional policies.

Several reasons provided by those who considered data ownership as a challenge highlighted clashes between funders and country policies. For instance, a respondent in health sciences stated:

> *"Health data and records contain sensitive personal information. The funders of projects sometimes want these data to be open source. However, country Institutional review boards (IRBs) normally require that the data does not leave the country."*

Closely related to the above response is another who said:

> *"The company I work for has very clear guidelines that the data belongs to the organisation, not individual scientists and now funding agencies require data to be shared in open access repositories."*

Also on the issue of funding, one respondent highlighted issues of equity between researchers in the political North and those in the political South: "*The North being mainly sponsors believe they own the data by virtue of providing the funding. Sometimes whole data sets collected in Zimbabwe can only be found/accessed in the partner institutions in the North. This applies to both social and hard science research*."

10.10 Conclusion

This chapter has presented the results of an online survey carried out on researchers in Zimbabwe. The main purpose of the survey was to complement the bibliometric results presented in the previous chapters. The survey data allowed for the exploration of details about collaboration patterns and experiences that could not be captured by the bibliometric analysis. The chapter was guided by two research questions:

1. What are the reasons for research collaboration?
2. What challenges are faced by researchers when in Zimbabwe when engaging in research collaboration?

Before these questions were addressed, the demographic details of respondents were provided. About half of the respondents who completed the survey were young scientists. The major findings of the chapter are presented under the following headings:

10.10.1 Reasons for research collaboration

Reasons for engaging in research collaboration were grouped into two broad themes; namely, instrumental and intrinsic factors. Intrinsic reasons were cited as the main reasons for engaging in research collaboration. These included knowledge-based rationales such as access to knowledge, skills and expertise, research productivity, and personal gains.

10.10.2 Aspects considered by researchers when selecting research collaborators

A factor analysis, specifically a Principal Component Analysis (PCA), was performed in order to group 13 variables about factors used by researchers when considering collaborators into sets of coalescing items. The analysis grouped the variables into four components; namely, demographic homophily, access to resources, skills and expertise, and good work ethics. Of these four, demographic homophily, with a mean score of 0.9 out of 10, was viewed as the least important when choosing research collaborators. Unique and complementary skills, with a mean score of 9.2 out of 10, was considered the most important. The four components were then treated as a new variable and were used to measure how choices of collaborators differed according to regions and the research career stages of individuals. It was found that there were no significant differences among the mean scores of the regions. Meaning, respondents regarded components equally.

10.10.3 Challenges faced by researchers in Zimbabwe when engaging in research collaboration

A PCA was performed in order to group 24 variables about challenges faced by researchers during collaborations into sets of coalescing items. The analysis grouped the variables into five components; namely, dishonesty and trustworthiness; issues of management and control; lack of homophily; disregard for research support staff; and unclear demarcation of collaborator roles. Of these components, with a mean score of 6.0 out of 10, unclear demarcation of collaborator roles was considered as a major problem, while lack of homophily, with a mean of 2.3, was not seen as a major problem. Each component was then treated as a new variable and was used to determine the extent to which challenges faced by researchers in the country differed according to regions and research career stages. Having performed a one-way ANOVA of variance, two components – dishonesty and untrustworthiness, and unclear demarcation of collaborator – had significant statistical differences among the mean scores of each of the components. Respondents who collaborated with researchers in Zimbabwe only considered dishonesty and untrustworthiness as a major problem as compared to respondents who collaborated with ZW and RoA. Unclear demarcation of collaborator roles was cited as a major problem for researchers who collaborated with individuals in Zimbabwe only as compared to those who collaborated with ZW & RoW. Of the four components – demographic homophily, access to resources, skills and expertise, and good work ethics – demographic homophily, with a mean score of 0.9 out of 10, was viewed as the least important when choosing research collaborators. Unique and complementary skills, with a mean score of 9.2 out of 10, was considered the most important.

The four components were then treated as a new variable and were used to measure how choices of collaborators differed according to regions and the research career stages of individuals. It was found that there were no significant differences among the mean scores of the regions. Meaning, respondents regarded components equally.

10.10.4 Authorship disputes

The study found that authorship disputes were mainly faced by those in research groups with more than six individuals. Researchers faced disputes especially when they collaborated with individuals from outside of Zimbabwe. A high percentage of researchers who faced disputes were in health sciences. These individuals also worked in large research groups. Disputes were mainly about, in order of selection, which author names should be reflected on articles; which collaborators to list as authors in an article; and which collaborators to mention in the acknowledgement of an article. About 61% of respondents reported that disputes were normally resolved. The most common responses provided about how disputes were resolved were: disputes resolved after considering individual contribution; disputes resolved after discussions and consensus; and intervention of principal investigator/mentor/funder.

Asked how co-authorships came about, most respondents revealed that co-authorships were either informally negotiated among members of research groups on case-to-case bases, or researchers followed common practices in their research fields. The most appropriate stage to discuss of issues of co-authorship reported was during the conceptualisation phase of the research.

10.10.5 Data ownership and data sharing

Respondents revealed that they shared research data with one or more Zimbabwean researchers and even with international researchers. Use of data that belonged to others was more common in the agricultural sciences and natural sciences. Most researchers reported that they had never experienced issues of disputes regarding data ownership and data sharing. The few who did said that the issues were mainly about who had rights to the data.

CHAPTER 11
Discussion and conclusions

11.1 Introduction

The results of a bibliometric analysis of research production and research collaboration in Zimbabwe have been presented in the previous chapters. This chapter discusses the findings of this work in light of the four research objectives:

- to determine how the profiles of research production and research collaboration in Zimbabwe differ based on the data sources that are used (i.e. Scopus, WoS and the National Research Database of Zimbabwe [NRDZ])
- to determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed as compared to when author-level datasets are analysed
- to introduce a focus on INOs in bibliometric studies by developing a new classification framework of authorship types that accommodates the phenomenon of INOs as a form of international participation, and applying it to Zimbabwe's research; and,
- to explore the value that context adds to the bibliometric analyses of Zimbabwe's research production and collaboration, where 'context' is dealt with in two ways – firstly, by analysing the bibliometric data within time periods that are rooted in socio-political reality, and, secondly, by supplementing the bibliometric data with survey data.

11.2 Addressing research objective 1

> *Research objective 1: To determine how the profiles of research production and research collaboration in Zimbabwe differ based on the data sources that are used (i.e. Scopus, WoS and the National Research Database of Zimbabwe [NRDZ]).*

The study did not rely on a single mainstream database but on two such databases (WoS and Scopus) for the analysis of research production and research collaboration in Zimbabwe. The two databases were integrated and unified to create a new database of Zimbabwean articles and supplemented with articles from the NRDZ. Analysis of the representation of Zimbabwe's articles showed that Scopus has a relatively higher coverage of articles produced by researchers in the country, as compared to WoS. The higher coverage of articles in Scopus has been confirmed in previous studies. An early study by Norris and Oppenheim (2007) showed that the overall coverage of journals in Scopus was more comprehensive than the WoS: approximately 16 000 journals in Scopus compared with 9 500 in the WoS. Similarly, Ocholla, Mostert and Rotich (2016) found the visibility of two South African universities in Scopus greater than in WoS. When a third bibliographic data source (NRDZ) was added to reflect on the value of using a national research database as a bibliometric data source, it was found that the NRDZ contributed little in the way of additional articles to those already indexed in the WoS and Scopus databases.

Additionally, when indicators derived from Scopus and WoS data were compared with the indicators based on all three data sources combined (i.e. Scopus, WoS, NRDZ), little, if any, differences, were observed (see Chapter 6). The NRDZ contributed only 9% of Zimbabwe's article output not already indexed in any of the two global databases, in the period 2012-2016. This is despite the fact that the NRDZ is considered as a comprehensive 'one stop shop' covering all public domain research in the country (RCZ, 2019). Table 11.1 shows the unique contribution of the NRDZ to Zimbabwe's article output, based on a summary of relevant results from Chapter 6.

Table 11.1: Unique contribution of NRDZ data to article output in Zimbabwe overall, and per sector and field

Sector	Number of articles	Unique NRDZ contribution		Field	Number of articles	Unique NRDZ contribution
Overall	2935	9%		Natural sciences	1033	12%
University sector	2166	13%		Social sciences	637	14%
Government sector	514	4%		Humanities	210	14%
INO sector	415	1%		Health sciences	947	3%
NGO sector	274	1%		Agricultural sciences	401	1%
Other national sectors	164	1%		Engineering & technologies	88	1%

Table 11.1 shows that the largest contribution of the NRDZ was in the university sector, where its unique contribution to the total article output in that sector was 13%. Also in the fields of social sciences and humanities, the NRDZ was found to have made notable contributions to the total article outputs in the two fields (14%), in addition to the contributions made by Scopus and WoS. One explanation for the high counts of social sciences and humanities in the national database could be the fact that these fields are under-represented in mainstream Scopus and WoS databases. Hence researchers publish in other journals, not indexed in the mainstream databases. This argument is supported in literature, for instance by Mouton and Blackenberg (2018), as well as by Sugimoto and Larivière (2018) who showed that Scopus and WoS have a relatively low coverage of social sciences and humanities fields. It could also be that researchers in the humanities and social sciences have a greater awareness of and

tendency towards uploading their publications, or at least the details of their publications, unto a national repository.

Additionally, the study determined how the addition of NRDZ articles would influence indicators of research production in the case of Zimbabwe. Table 11.2 summarises the results (taken from Chapter 7). It reports the percentage share of articles produced by a sector in a particular field, compring the shares reported for Scopus and WoS data, on the one hand, to the shares reported for Scopus, WoS and NRDZ data, on the other hand. The table shows, for instance, that when Scopus and WoS were used to compute article output indicators, the university sector was found to be responsible for 64% of articles in health sciences. When NRDZ data were added to the Scopus and WoS data, the university sector was responsible for 65% of the article output in health sciences. This means the addition of NRDZ data accounted for a negligible change of 1% in the value of the indicator, as compared to relying on Scopus and WoS data alone. In overall, the addition of NRDZ data to Scopus and WoS data provides little additional value, as the values of the relevant indicator (percentage of articles produced) across the two sets of data are either the same or almost the same.

Table 11.2: Percentage of articles produced by a certain sector in a particular field: the 'value-add' of NRDZ data in relation to Scopus and WoS

Fields	Data sources used	Sectors				
		University sector	Government sector	NGO sector	INO sector	Other national sectors
Health sciences	Scopus & WoS	64%	25%	19%	17%	9%
	Scopus, WoS & NRDZ	65%	25%	18%	17%	8%
	Value-add (difference)	*1%*	*0%*	*1%*	*0%*	*1%*
Natural sciences	Scopus & WoS	72%	18%	9%	14%	6%
	Scopus, WoS & NRDZ	75%	17%	9%	13%	5%
	Value-add (difference)	*3%*	*1%*	*0%*	*1%*	*1%*
Agricultural sciences	Scopus & WoS	66%	15%	2%	37%	5%
	Scopus, WoS & NRDZ	66%	15%	1%	37%	5%
	Value-add (difference)	*0%*	*0%*	*1%*	*0%*	*0%*
Social sciences	Scopus & WoS	77%	12%	9%	7%	5%
	Scopus, WoS & NRDZ	80%	11%	8%	6%	4%
	Value-add (difference)	*3%*	*1%*	*1%*	*1%*	*1%*
Engineering and technologies	Scopus & WoS	91%	9%	1%	3%	2%
	Scopus, WoS & NRDZ	91%	9%	1%	3%	2%
	Value-add (difference)	*0%*	*0%*	*0%*	*0%*	*0%*
Humanities	Scopus & WoS	85%	10%	1%	2%	5%
	Scopus, WoS & NRDZ	87%	9%	1%	1%	4%
	Value-add (difference)	*2%*	*1%*	*0%*	*1%*	*1%*

Table 11.3 focuses on the percentage share of co-authored articles in a field or sector, as an indicator of research collaboration. The data were taken from the analyses in Chapter 6. The table shows that the addition of NRDZ demonstrated little 'value add', also in the case of an indicator of research collaboration. For instance, based on Scopus and WoS data, 93% of natural sciences articles produced between 2012 and 2016 were found to be co-authored. When NRDZ data were added, a small value-add of 4% was noted. This is the highest value-add in all fields and sectors.

Table 11.3: Percentage of co-authored article in each of the fields and sectors: the 'value-add' of NRDZ data in relation to Scopus and WoS

Fields and sectors		Scopus & WoS	Scopus, WoS & NRDZ	Value-add (difference)
Field	Natural sciences	93%	89%	4%
	Social sciences	77%	74%	3%
	Humanities	49%	46%	3%
	Agricultural sciences	98%	98%	0%
	Health sciences	97%	97%	0%
	Engineering and technologies	93%	93%	0%
Sector	University sector	87%	84%	3%
	Government sector	96%	96%	0%
	NGO sector	99%	99%	0%
	INO sector	98%	98%	0%
	Other national sectors	91%	91%	0%

Generally, the study found that the NRDZ contributed little to the existing Scopus and WoS data. The low coverage of Zimbabwe's articles in the NRDZ could be explained by two factors. Firstly, as already shown in the literature, researchers are sceptical of populating repositories, especially without any clear incentives for doing so (Raju and Raju, 2009). Secondly, not all journals permit self-archiving of published research in repositories. Although Open Access (OA) models such as gold Open Access, do permit self-archiving of published material, such models require authors to pay publication fees for articles to appear as OA in journals that publish closed access articles (Björk, 2017). This calls for research institutions in the country to provide the necessary financial resources for ensuring that research articles appear in OA journals in order for such articles to be uploaded to the NRDZ. It also calls for research institutions in the country to invest in a core set of OA national journals that meet certain quality criteria for eventual incorporation in a non-commercial, regional bibliographic database. It was noted that some research departments in the country had, to date proposed the establishment of national journals. For instance, the Zimbabwean Comprehensive Agricultural Policy Framework for 2012-2032 highlights the need to increase the number of research publications in agriculture by 2032. Two relevant statements of action in the policy are to facilitate the establishment of national agricultural journals and to provide “financial resources … to enable researchers to pay for scientific publication in regional and international peer-reviewed journals” (Ministry of Agriculture, Mechanization and Irrigation Development, 2012, p. 19).

What can therefore be used for future bibliometric studies of Zimbabwe, other than relying on the NRDZ? Since researchers are sceptical when it comes to populating the national local research database, a compilation of local journals in the country can be made and used for bibliometric analysis. The challenge however is that most national journals in the country are either irregular or ceased publishing. For example, the *Zimbabwe Science News* published by the Zimbabwe Scientific Association had its first issue in 1967 and has since ceased publication. In addition, the *Southern Africa Journal of Education, Science and Technology* published by Bindura University of Science Education had its first issue in 2006 but has had irregular issues since 2008.

The lesson learnt from the study is that combining Scopus and WoS data for a bibliometric study provides an adequate and comprehensive coverage of Zimbabwean articles. Instances where the coverage of one journal in a certain data source ceased, but continued in the other data source, were noted. For instance, the *Central African Journal of Medicine* had consistent indexing in WoS from 1980 until 1993. From 1994 onwards, only Scopus indexed the journal. Relying on only one database would underrepresent the *Central African Journal of Medicine*.

The study established that Zimbabwe’s total research output for the period 1980-2016, as measured by the numbers of articles in the Scopus and WoS databases (i.e. based on full paper counting), increased over the period under review. A compound annual growth rate of 4.6% was recorded. The increase in the country’s article output is similar to that of other African countries, as reflected in the literature. For example, Mouton and Blanckenberg (2018) showed that Africa’s research annual output has been steadily increasing over the past decades. This increase is attributed to a number of factors, among which, “… the accumulative effect of increased international collaboration between foreign scientists and African scientists in multi-authored teams in fields such as high-energy physics, infectious diseases and tropical medicine” (Mouton 2018, p. 12).

In terms of research production in the different national sectors, based on the Scopus and WoS dataset, the university sector was found to be the most productive sector. The sector was responsible for about two-thirds (66%) of the country’s article output produced between

1980 and 2016. This was followed in second place by the government sector with a percentage contribution of 24%. In third place was the international national organisation (INO) sector, with a contribution of 11%. Within the university sector, the University of Zimbabwe (i.e. the oldest university in the country established during the colonial era in 1957), accounts for more than half of the articles produced in the country. For example, between 2009 and 2016, the University of Zimbabwe, with a percentage contribution of 58%, produced the majority of articles in the field of health sciences in the country. It accounted for 90% of all health articles within the local university sector. The University of Zimbabwe also produced 55% of all articles in the natural sciences in the country, and accounted for 63% of natural sciences articles within the university sector.

The study showed that collaboration varied across time, fields and sectors. For example, in terms of national collaboration, during the first and second periods, researchers and academics in the country collaborated more with their colleagues in the same instituitions (intra-institutional co-authorship). However, in the last two periods, researchers/academics increasingly collaborated with others from different institutions (inter-institutional co-authorship). In terms of international collaboration, the study found that in the first two periods, researchers in Zimbabwe collaborated more with countries outside Africa – mostly the US and UK. These results are not surprising as it has been reported that many of Africa's R&D organisations, specifically institutions in higher education, are largely dependent on foreign funding for their R&D performance. This funding is often linked to a northern based principal investigator (e.g. USA or EU), who by default is indicated as an international co-author of publications emanating from this research (CREST, 2019). However, for Zimbabwe, in the last two periods, researchers in the country began collaborating more with the rest of Africa. South Africa emerged as the top collaborator amongst all African countries.

11.3 Addressing research objective 2

> *Research objective 2: To explore the value that context adds to the bibliometric analyses of Zimbabwe's research production and collaboration, where 'context' is dealt with in two ways – firstly, by analysing the bibliometric data within time periods that are rooted in socio-political reality, and, secondly, by supplementing the bibliometric data with survey data.*

As already highlighted in chapter 1, context is defined in the Cambridge English dictionary as 'the situation within which something exists or happens, and that can explain it'. In bibliometrics, context can either be applied or constructed. Through application, external factors such as social, institutional and technical envirnoments within which research takes place are incorporated in the analysis to explain trends and patterns. In terms of construction, bibliometric results are used to generate context for other studies or interested parties. Although it can be argued that all bibliometric studies generate context and therefore are not context free, the focus in this study was on the application of context in bibliometric analysis. This was done in two ways. Firstly, by analysing the bibliometric data within time periods that are rooted in socio-political reality of Zimbabwe, and, secondly, by supplementing the bibliometric data with survey data.

Following independence in 1980, Zimbabwe underwent a series of events that negatively affected all societal sectors, including human capital and R&D. This study incorporated this context into the analysis by developing a socio-political timeframe and by using that frame to study trends in the data over time. This timeframe represented four periods. Period One (1980-1990): *Independence, vibrant economy, and neo-socialist policies*; Period two (1991-1997): *Adoption of Economic Structural Adjustment Programme (ESAP), natural disasters and global recession*; Period three (1998-2008): *Land reforms, sanctions, international isolation, and hyperinflation* and, Period four (2009-2016): *Government of National Unity, years of recovery and slow economic growth*.

As indicated in Chapter 2, Section 2.9, three unknown effects of the socio-political periods on research production and research collaboration in Zimbabwe were being scrutinized. The three unknowns that the study sought to make explicit were:

1. How do the four periods correspond to time-based differences in the **research production** of universities, sectors, and fields in Zimbabwe ?
2. How do the four periods correspond to time-based differences in **national research collaboration** in universities, sectors, and fields in Zimbabwe?
3. How do the four periods correspond to time-based differences in international research participation in Zimbabwe's research, as reflected in **international research collaboration** and **participation of INOs**?

Analysing how the application of context relates to research production by Zimbabwean organisations in the different sectors, 1980-2016

The previous chapters provided detailed bibliometric analyses of the trends and patterns of research production of the different Zimbabwean organisations. This section brings together these results and provides summaries of how context relates to research production in the country. Only two fields (i.e. health sciences and agricultural sciences) out of the six broad fields are referred to. Table 11.1 provides a summary profile of percentage shares of articles produced in health sciences by national sectors within the four socio-political periods. It also shows how the values of the indicators changed between the four periods. The green part indicates that the share of research production increased, the red part indicates that research production went down while the yellow means production stayed the same.

Based on Table 11.1, it can be seen, as indicated by the green parts, that overally, research production by the different national sectors increased with time. The government sector, as indicated by the red and yellow marks, is the only national sector in the country that did not show an upward trend, rather its share of research production decreased in the period under review. The proportional contribution of the government sector dropped by 2% from period one to two, and by 6% from period two to three. Its contribution remained constant in the third and fourth periods. One explanation for this decrease is that the the government sector was more likely to have been affected by the socio-political challenges faced by the country at the time. Prior to 2000, Zimbabwe had relied on donor sources for much of its research funding. However, by 2003, most donors had suspended their operations (Beseda & Moyo, 2008). Although some sectors which had long standing relations with internations organisations continued to receive funding, most foreign funding to government ceased (Ibid). By 2003, expenditure on R&D activities in the country was recorded as one of the lowest in the world (Ibid).

The NGO and INO sectors had, as shown by the green marks in Table 11.1, to some extent, notable upward changes. Both these sectors directly and indirectly rely on international partners for funding. Ng'ethe (1991) for instance noted that local NGOs are run by local people but are largely dependent on foreign resources. Likewise, INOs are run by local people but receive financial support from their headquarters located in foreign countries. The Elizabeth Glaser Pediatric AIDS Foundation (EGPAF) for example, is an INO (i.e. international NGO) involved in health research in Africa, and has its headquarters in Washington, United States of America (USA). The organisation's research activities are located in its Global Research Unit, which works closely with country-based staff, ministries of health, and other partner organisations (EGPAF 2020).

Table 11.1: Summary profile of percentage articles in health sciences, by national sector and socio-political period

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% articles by the university sector	66%	68%	69%	65%	+2%	+1%	-4%
% articles by the government sector	31%	29%	23%	23%	-2%	-6%	0%
% articles by the NGO sector	2%	3%	9%	20%	+1%	+6%	+11%
% articles by the INO sector	1%	5%	12%	15%	+4%	+7%	+3%
% articles by other national sectors	3%	3%	4%	8%	0%	+1%	+4%

Table 11.2 provides a summary profile of the percentage shares by the five most productive organisations in health sciences. The percentages for each organisation are calculated from the total number of articles produced in each national sector. Table 11.2 shows that generally, with the exception of the Biomedical Research and Training Institute, there were insignificant changes in the shares of articles produced by the organisations. The Biomedical Research and Training Institute recorded a high percentage increase of 42% between periods 2 and 3. The institute as already mentioned in Chapter 2, is a recognised centre for international collaborative research and training with a focus on HIV/AIDS, tuberculosis and malaria (UNESCO, 2014). In 2013, it produced 5.38% of the country's publication output (i.e. third following the University of Zimbabwe and the Bindura University of Science Education (ibid.).

Although Table 11.2 shows that the proportional share of health articles produced by the University of Zimbabwe decreased with time, as indicated by the red marks, the university maintained its dominant status. It contributed the larger share of health sciences articles in the four periods. One reason, among other factors for the dominance of the university in production of health sciences articles is that the University of Zimbabwe Clinical Research Center (UZ-CRC), which is the country's highest funded centre, has longstanding partnerships with the University of California, San Francisco (Hodgkinson & Pasirayi, 2015). The centre also benefits from international donors such as the Bill and Melinda Gates Foundation, the WHO, and the Wellcome Trust. Even though most research institutes in the country were going through series of challenges that affected research activities, researchers in the health sciences at the University of Zimbabwe were able to withstand some of the country's socio-political challenges due to the availability of international funding and partnerships (Hodgkinson & Pasirayi, 2015).

Table11.2: Summary profile of % articles by five most research productive organisations in health sciences, by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% articles by the University of Zimbabwe (University sector)	100%	100%	98%	90%	0%	-2%	-8%
% articles by the Ministry of Health and Child Care (Government sector)	78%	80%	79%	83%	2%	-1%	+4%
% articles by the Biomedical Research and Training Institute (NGO sector)	-	14%	56%	49%	--	+42%	-7%
Zvitambo (NGO sector)	-	-	19%	22%	--	--	+3%
% articles by the Centre for Sexual Health and HIV AIDS Research Zimbabwe (CeSHHAR) (NGO sector)	-	-	-	12%	--	--	--

Table 11.3 presents a summary profile of the prorpotional share of agricultural articles produced by five broad national sectors. The table shows that of all the sectors, the contribution by the government sector continued to decrease over time. This is despite the fact that the government sector employs more FTE reasearchers in agriculture than any other sector in the country (ASTI, 2020). The decrease in the contribution by the sector is largely attributed to a series of challenges that affected the country's agricultural human capital base and R&D activities. Flaherty et al. (2011) reported that the Department of Research and Specialist Services (DRSS) (i.e. the most prominent agricultural research organisation in the country), accounted for up to two-thirds of national agricultural research investments and human resource capacity in the 1980s and early 1990s. It had more than 150 FTEs in the early 1990s. However, due to the country's political and economic constraints, by 2008 it employed less than a quarter of the nation's research staff (i.e. 35 FTE ressearchers).

Once the government sector struggled to support research activities, other sectors, specifically INOs, emerged as key producers of agricultural research. Table 11.3 shows that the contribution by the INO sector consistently increased. Although it might have been expected that international participation in Zimbabwe's research would decrease due to international isolation and economic sanctions, the contribution by the INO sector increased. In fact, between 2009 and 2016, INOs contributed 36% of country's total reseach output in agricultural sciences (i.e. second after the university sector). The reason, as noted by Flaherty, Chipunza and Nyamukapa (2011) is that during the 2000s, research collaboration with regional and international organisations was constrained. However, some international research organisations continued to operate in the country. Some of which, the International Maize and Wheat Improvement Center (CIMMYT) with its headquarters in Mexico, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) based in India. These organisations contributed to the research production of agricultural articles in the country.

Table11.3: Summary profile of percentage article in agricultural sciences by national sector and socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% articles by the university sector	38%	53%	59%	63%	+15%	+6%	+4%
% articles by the INO sector	8%	12%	23%	36%	+4%	+11%	+13%
% articles by the government sector	54%	39%	25%	17%	-15%	-14%	-8%
% articles by the NGO sector	-	1%	2%	2%	-	+1%	0%
% articles by other national sectors	4%	3%	2%	5%	-1%	-1%	+3%

Table 11.4 shows a summary profile of the six most productive organisations in agricultural sciences in the four periods. The table shows that the International Maize and Wheat Improvement Centre (CIMMYT), an INO, recorded the highest percentage increase of 28% in the last period. On the other hand, the University of Zimbabwe had a significinat decrease of 20% in the last period. This decrease is largely attributed to the emergence of other universities to produce agricultural sciences articles.

What, therefore, can be learnt from the periodisation framework created in the study? And how does the framework relate to the research production of universities, sectors and fields in Zimbabwe?In terms of research production there were insignificant changes in the shares of articles produced by the organisations. The summary profiles of percentage shares of articles produced by national sectors within the four socio-political periods, provided in this section showed that the values of the indicators changed insignificantly between the four periods. Of all the sectors, the government sector is the only sector whose contribution to the total article output decreased with time. This indicates, as already explained, that the government sector was mostly affected by the socio-political conditions prevailing in the country. The Scientific Industrial Research and Development Centre (SIRDC, 2003) for example, reported that Zimbabwe's expenditure on research and development R&D, at the turn of the century, was only about 0.2% of the country's gross national product. Which means the government struggled to fund R&D activities in the country.

The application of context in bibliometric analysis aids in explaining trends and patterns. For instance, context helps in understanding why from 1991 onwards INOs became the second contributor of agricultural research articles in the country. It also helps in understaning why some organisations, such as the University of Zimbabwe Clinical Research Center (UZ-CRC) continued to produce the largest share of health science articles, even though other research institutes in the country were going through series of challenges that affected research activities. The next section provides summaries of how context affected the trends and patterns of research collaboration in the country.

Table 11.4: Summary profile of percentage articles by six most research productive organisations in agricultural sciences, by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% articles by the University of Zimbabwe (university sector)	100%	100%	88%	68%	0%	-12%	-20%
% articles by the International Maize and Wheat Improvement Centre (CIMMYT) (INO sector)	20%	21%	31%	59%	+1%	+10%	+28%
% articles by the Ministry of Lands, Agriculture and Rural Settlement (government sector)	88%	76%	86%	82%	-12%	+10%	-4%
% articles by the International Crops Research Institute for Semi-Arid Tropics (INO sector)	47%	30%	27%	28%	-17%	-3%	+1%
% articles by Bindura University of Science Education (university sector)	-	-	5%	14%	-	-	+7%
% articles by Chinhoyi University of Technology (university sector)	-	-	2%	12%	-	-	+10%

Analysing how the application of context relates to trends and patterns of national and international research collaboration in Zimbabwe, 1980-2016

This section discusses the extent to which context affected the trends and patterns of research collaboration in universities, sectors, and fields in Zimbabwe. Tables 11.5 and 11.6 show summary profiles of the proportional shares of co-authored articles produced by national sectors and fields in the four socio-political periods. With the exception of the humanities, the number of articles produced through co-authorship increased in all fields and sectors. The field of engineering and technologies recorded the highest percentage increase in the number of co-authored articles (33%) between periods 1 and 2. Similary, the NGO sector recorded the highest percentage increase of 26% between the first two periods. The results in the tables indicate that, despite periods of economic and political turmoil, the percentage shares of articles produced through co-authorship increased throughout the four periods.

The reasons for the increase in the number of articles produced through co-authorship can be extracted from the survey, where both intrinsic and instrumental factors were identified as the main reasons for conducting collaborative research. Intrinsic factors included individual choices and preferences such as knowledge-based rationales, including access to diversified skills and expertise, boosting productivity, and personal gains. Instrumental factors related to resource-based rationales such as access to resources and special equipment. Despite the individual reasons for engaging in research collaboration, the government of Zimbabwe in its second Science and Technology policy document, calls "… on tertiary institutions to engage in relations geared for collaborative research between research institutes nationally, regionally and internationally" (Second Science and Technology Innovation Policy of Zimbabwe, 2012, p. 15).

Table 11.5: Summary profile of percentage co-authored articles by field and by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% co-authored articles in agricultural sciences	63%	83%	94%	98%	+20%	+11%	+4%
% co-authored articles in health sciences	64%	85%	91%	97%	+21%	+6%	+6%
% co-authored articles in natural sciences	54%	74%	84%	93%	+20%	+10%	+9%
% co-authored articles in social sciences	30%	51%	65%	75%	+21%	+14%	+10%
% co-authored articles in humanities sciences	18%	16%	29%	50%	-2%	+13%	+21%
% co-authored articles in engineering and technologies	25%	58%	71%	92%	+33%	+13%	+21%

Table 11.6: Summary profile of percentage co-authored articles by sector and by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% co-authored articles by the university sector	54%	77%	85%	88%	+23%	+8%	+3%
% co-authored articles by the government sector	61%	79%	88%	96%	+18%	+9%	+8%
% co-authored articles by the NGO sector	54%	80%	85%	97%	+26%	+5%	+12%
% co-authored articles by the INO sector	71%	76%	89%	98%	+5%	+13%	+9%
% co-authored articles by Other sectors	45%	57%	83%	91%	+12%	+26%	+8%

Tables 11.5 and 11.6 showed profiles of the proportional shares of co-authored articles produced in the country. The focus shifts to the different types of collaboration. Table 11.7 illustrates how different types of research collaboration in Zimbabwe changed in the four periods. The results in the table, as demonstrated by the different colours, show that, while the percentages of articles produced through national collaboration only decreased in the four periods, those produced through international collaboration only, and through both international and national collaboration only, increased with time. For example, the number of articles produced through national collaboration only significantly decreased by 20% in the first two perods and continued to drop by 25% and 4% in the third and last period respectively.

It can be argued that, due to lack of funding for research in the country, researchers had no choice but to pursue collaborations with scholars from outside Zimbabwe. The survey results revealed that researchers engaged in collaborative research because of instrumental factors such as gaining access to resources and funding for research. It is also revealed in the literature that researchers prefer collaboration with those from high income countries (Confraria et al., 2020; Guns & Wang, 2017). This preference is steered by a need to gain access to research infrastructure and funding, and to build research capacities and scientific networks (Confraria et al., 2020). Additionally, it is hypothesised that smaller countries may have fewer single country publications due to the scarcity of collaboration opportunities at the national level (Narin et al., 1991). The argument here is that collaborative efforts are initiated by researchers in small countries who cannot find collaborators.

Table 11.7: Summary profile of percentage co-authored articles by different types of collaboration, by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% national co-authored articles only	72%	52%	27%	23%	-20%	-25%	-4%
% international co-authored articles only	24%	39%	52%	42%	+15%	+13%	-10%
% both national and international co-authored articles only	4%	9%	21%	35%	+5%	+12%	+14%

Table 11.8 shows a summary profile of the percentage number of national co-authored articles. The table shows a significant decrease of 56%, in the last period, in the number of articles produced through intra-institutional co-authorship, and a steady increase of 19% in the same period, in the number of articles generated through both intra- and inter-institutional co-authorship. These results indicate that the patterns of national collaboration changed over time. Researchers steadily shifted from collaborating with colleagues from within their own institutions to collaborating with others in different institutions in the country.

Table 11.9 provides a summary of the percentage number of international co-authored articles produced by Zimbabwe between 1980 and 2016. The results in the table show a decrease in the number of articles produced in co-authorship with the rest of the world only. For example, a significance decrease of 25% was recorded in the last period for articles produced in co-authorship with the rest of the world. On the other hand, an increase in the number of articles co-authored with the rest of Africa and those co-authored with both the rest of Africa and the rest of the world was recorded. For example, an increase of 19% in the number of articles produced through both national and international co-authorship was recorded for the last period.

Generally, the results show a steady shift in the participation of foreign countries in Zimbabwe's research. In the early 1980s and 1990s, researchers from the rest of the world contributed the largest share of international co-authorship. African participation became more visible in the later years, especially in the last two periods. It is revealed in the results chapters that, even though some individuals still collaborated with the UK and the USA, in the last period, South Africa emerged as the main collaborating partner for Zimbabwe. One reason for South Africa dominating the last period could be a reflection of the establishment of new networks between emigrants from Zimbabwe to South Africa. Another reason could be the result of Zimbabwean researchers studying in South Africa. According to the UNESCO Institute of Statistics (2020), the top destination country for Zimbabwean students in 2017 was South Africa (57%). It is generally assumed that when researchers study abroad, they tend to maintain their overseas research groups and research partners, even after returning to their home country (Adams et al., 2014).

Was the application of context in bibliometric analysis worthwhile? To a greater extent, the application of context in the bibliometric analyisis was worthwhile. Putting context into perspective helped to explain research collaboration trends and patterns. Context aided in explaining why prior to 2000, research production in agricultural sciences was mainly dominated by the government sector, but at the turn of the century, the government sector contributed the least to agricultural research production in the country. In terms of research collaboration, context helped explain why there was a steady shift in the participation of foreign countries in Zimbabwe's research (i.e from collaborating more with researchers from the rest of the world to collaborating more with researchers from Africa).

Although the periodisation framework had some benefits, in some cases, categorisation in four periods may have masked some trends in the data. Additionally, considering the fact that Zimbabwe is a country with a small science system, some fields, such as the humanities and the engineering and technologies had fewer number of articles. Categorising these articles in four periods seemed to be impractical.

Table 11.8: Summary profile of percentage national co-authored articles in Zimbabwe, by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% co-authored articles within national institutions only	92%	84%	61%	5%	-8%	-23%	-56%
% co-authored articles between national institutions only	6%	10%	25%	12%	+4%	+15%	-13%
% co-authored articles between and within national institutions only	2%	6%	14%	33%	+4%	+8%	+19%

Table 11.9 Summary profile of international co-authored articles in Zimbabwe by socio-political period, 1980-2016

Indicators	Period 1	Period 2	Period 3	Period 4	Changes		
					P1-P2	P2-P3	P3-P4
% co-authored articles rest of Africa only	20%	13%	18%	27%	-7%	+5%	+9%
% co-authored articles with rest of world only	73%	77%	62%	37%	+4%	-15%	-25%
% co-authored articles with both rest of Africa and rest of world	8%	10%	20%	37%	+2%	+10%	+17%

Use of survey to provide context for bibliometric data

In addition to analysing the bibliometric data within time periods that are rooted in the socio-political reality of Zimbabwe, the study supplemented bibliometric data with survey data. The survey generated additional insights into collaboration patterns and experiences of Zimbabwean researchers that could not be captured by the bibliometric analyses. It also provided explanantions for some of the research collaboration trends and patterns. For example, the reasons for the increase in the number of articles produced through co-authorship were extracted from the survey results. These reasons included both intrinsic and instrumental factors. instrisic factors such as access to diversified skills and expertise were the most cited. These factors were also considered important by researchers in Kenya, as reported by Muriithi et al (2018), who found that access to resources and skills and expertise are the main factors considered by researchers in Kenya when choosing collaborators.

In addition to providing reasons for co-authorship, the survey also provided reasons for single authorship. Based on the bibliometric data, it was found that out a total of 10 753 articles produced Zimbabwe between 1980 and 2016, 2 285 (21%) were generated through single authorship. Besides the fact that some fields such as the humanities produced most a rticles through single authorship, the survey provided additional information as to why some researchers seldom engaged in research collaboration. The reasons cited by respondents were: (i) too heavy workload, (ii) lack of resources, (iii) lack of incentives and rewards, and (iv) bad collaboration experiences. These were also cited in previous studies as hurdles that hinder researchers from engaging in collaborative research. For example, in their study, Mouton et al. (2018) identified obstacles such as inability to find partners for collaboration, lack of resources, lack of funding, language barriers, and institutional barriers.

The survey also gathered information about authorship disputes. This could not be ascertained in the bibliometric data. The study found that disputes vary across fields, career stages of researchers and size of research teams. A high percentage of researchers who faced disputes were in health sciences. These individuals also worked in large research groups. Previous studies reveal that fields with high levels of collaboration (e.g. the health sciences) are more likely to experience authorship disputes as compared to those who collaborate less (e.g. mathematics). This explains why, as remarked by Ross et al. (2008), biomedical and health science scholars pay much more attention to unethical authorship practices than other disciplines do. In a review of the literature on authorship issues, Marusic et al. (2011) found that two thirds of studies of unethical authorship practices were from the fields of biomedical and health sciences, while only one third of the studies were from natural and health science fields. Disputes faced by Zimbabwean researchers were mainly about, in order of selection, which author names should be reflected on articles; which collaborators to list as authors in an article; and which collaborators to mention in the acknowledgement of an article. Baker et al. (2012) argued that in general, authors tend to give credit to researchers they think are more prestigious and whose names might add weight to the project. Other authors believe that some contributions are not worth attribution, while others insist that any form of contribution to research, including data gathering, warrants recognition in the form of co-authorship (Bozeman & Youtie, 2015).

The literature also shows that younger researchers might be less involved than older researchers in decision-making related to collaborative projects, and that the process might remain non-transparent to them. Some senior researchers might not consider students working with them on joint projects as collaborators; rather, they might see themselves more as teachers than as collaborators. This causes tension either way. Disputes are also more likely to increase in large research projects spanning countries, as compared to small research teams located within the same locations (Tsai et al., 2016). As highlighted by Katz and Martin (1997), with more people and perhaps several institutions involved, greater effort is required to manage the research. If the collaboration is large or spans a considerable distance, it might need more formal management procedures, which may create problems of bureaucracy.

The most common responses provided by researchers in Zimbabwe about how disputes were resolved are: disputes resolved after considering individual contribution; disputes resolved after discussions and consensus; and intervention of principal investigator/mentor/funder. However, Youtie and Bozeman (2016) show that dealing with authorship disputes can be a challenge. For example, they argued that despite the various approaches of solving authorship disputes, trade-offs occur. This happens when one type of action creates a number of other problems for instance, deciding on direct confrontation, particularly with hostile people, may cause problems down the road, especially if the difficult collaborators are in senior positions in the same academic department or field; and avoiding collaborations with difficult people poses the risk that less creative work may result; additionally, resolutions of contributorship problems through obtaining agreements in advance can be imagined to conflict with norms of fairness, interactive participation and the free flow of knowledge, and even the need for flexibility in the research process. What could work, as indicated in literature is the need for universities or department directors to contemplate problems and manage them to create friendly and fair collaborations.

In conclusion, the survey allowed for the exploration of details about research collaboration trends, patterns and experiences. These details could not be captured in the bibliometric analysis. The survey also provided explanations for the different authorship types. It in some way also provided context for the study. It is noted in the literature that very few bibliometric studies about research collaboration in Africa incorpoarate other data sources to reflect on research collaboration. The current study stands to show that studies on research collaboration benefit from the use of multiple methodologies, rather than a single approach.

11.4 Addressing research objective 3

> *Objective 3: To determine how profiles of research production and research collaboration in Zimbabwe differ when article-level datasets are analysed as compared to when author-level datasets are analysed.*

Research workforce of Zimbabwe, based on the author level bibliometric dataset

The study converted the article level database into a novel database of article authors. This allowed, for instance, identification of the research workforce in the country, the identification of sectors and fields with the highest concentration of the research workforce and the collaboration patterns of that workforce. Based on the author-level bibliometric dataset[26], a total of 2 896 Zimbabwean authors were identified as having been responsible for 3 584 Zimbabwean articles produced between 2009 and 2016. The majority of these authors were concentrated in the university sector (78%). Followed by those in in the government sector (33%), the INO sector (22%) and the NGO sector (15%). The majority (42%) of these authors were classified as publishing in the natural sciences. The second largest concentration of was in the health sciences (41%), followed by authors in the social sciences (28%). Only 20% of Zimbabwean authors were in the field of agricultural sciences[27]. Although the Zimbabwean government allocates 41% of its expenditure on R&D to agricultural sciences, a percentage that is four times higher than the African Union agricultural budget allocation[28], there are fewer researchers in the field. Echanove (2017) notes that the human resource component of the agricultural research and extension system in Zimbabwe has been shrinking due to political uncertainty and financial constraints. For this reason, the Zimbabwean government, in its most recent policy outline for agriculture, aims to establish the necessary human resource capacity

[26] Where authors and not the articles were used as the unit of analysis.
[27] The sum of percentages exceeds 100%, primarily because the field categories of article authors were not mutually exclusive, meaning an author could produce articles in more than one field.
[28] The African Union Commission, through the Maputo Declaration of 2003, encouraged member states to allocate at least 10% of their national budget towards agriculture.

for agricultural research (Ministry of Agriculture, Mechanization and Irrigation Development, 2012).

The results showed that a handful of researchers published articles using addresses that were classifiable in more than one sector and in more than one field. For example, about 69% of authors in the government sector also published articles with a university address as their affiliation. Two explanations were provided for this overlap: firstly, an issue of mobility, where researchers moved from one organisation to the other, and secondly, an issue of double affiliation, where researchers were affiliated with more than one institution at the same time. This could indicate that the same researchers could be responsible for the article output of a number of sectors and a number of fields. In this case, a follow-up study to find out if the same researchers were responsible for the article output of sectors and fields would be required.

The author level dataset also allowed the identification of authors with dual-national-international affiliations. It was found that out of a total of 2 896 Zimbabwean authors identified, 400 (14%), had dual national-international affiliations. The majority of these researchers were in the university sector, in the field of natural sciences, followed by those in the health sciences. These authors produced almost all their co-authored articles through international collaboration (99%). Which means the so-called researchers have more international links as compared to links with local researchers. What this study could not ascertain was where exactly these researchers were located. Such information can be gathered through the use of interviews. Generally, one of the greatest strengths of author level analysis is that shows authors with more than one affiliation. There is, as noted by Sugimoto and Laiviére (2018), a growing degree of co-affiliation, in which individual researchers are affiliated with more than one institution. In this case, a single authored article could be considered institutionally collaborative if an author is affiliated with more than one institution in an article (Sugimoto & Laiviére, 2018).

In addition to providing profiles of the research workforce, author-level analysis provides different insights when compared to analysis of headcounts or full-time equivalent (FTE) researchers. For example, based on the only known countrywide R&D survey carried out by UNESCO (2014) in Zimbabwe, a total of 1 315 FTE researchers were identified. The higher education sector was reported as having the highest percentage (92%) of FTE researchers in the country, while the government sector had about 8% of the total researchers. The current study places the contribution of universities to the scholarly research workforce at 75% and that of the government at 33%. The study also identified the research workforce in other sectors (i.e INO, NGO, Other sctors), not covered in Zimbabwe's R&D survey. Such author level bibliometric results have policy implications. The results can aid policy makers in making informed decisions about allocation of resources. That is, which sectors need to be prioritised when allocating resources and which ones are lagging behind in terms of human capital.

Trends and patterns of collaborating Zimbabwean authors: Comparison of indicators based on author-level and article-level datasets

The previous section discussed findings about profiles of the research workforce in Zimbabwe. This section focuses on the research collaboration trends and patterns of those researchers. A comparison between the shares of articles with collaboration (co-authorship) and the shares of article authors involved in collaboration (co-authorship) showed that using the two units of analysis produced different results. For example, as presented in Chapter 9, based on the article level bibliometric analysis it was found that 89% of all Zimbabwean articles produced between 2009 and 2016 were co-authored, while the author-level indicator showed that during that same period, 95% of all Zimbabwean authors had co-authored articles. What these results imply is that, as already pointed out in Chapter 9 is that although the two sets of indicators generally reveal a similar pattern of results, the results are not identical. This is because a single productive author can produce many articles. A decision regarding which finding to apply in a practical context (e.g. research policy context) would be a matter of emphasis – whether to emphasise the research performance (volumes of articles as output) or the research performer (the authors and their publishing characteristics).

While the article level dataset showed that 37% of Zimbabwean articles were produced through international collaboration only, the author-level dataset showed that only 13% of Zimbabwean authors produced articles through international collaboration only. A large number of authors, 52% produced both nationally and internationally co-authored articles, while 30% authors produced nationally co-authored articles only. This indicates that the majority of Zimbabwean authors produced articles through national collaboration. However, although the bulk of authors in the country collaborated nationally, those who collaborated with international partners produced more articles. For instance, the smallest number of authors (362) produced 1 334 articles through international co-authorship only. Authors in this category were the most productive as they produced, on average, 3.7 articles per author. Authors (1 512) producing articles (1 115) through both national and international co-authorship followed in terms of productivity, with a mean score of 0.7 articles per author. Authors (867) with articles (732) produced through national co-authorship only had the lowest mean score of 0.8. These findings are important for policy considerations as the most productive scholarly research workforce in the country is identified. Collaboration with international researchers is already supported by the Zimbabwean government. The government, in its second Science and Technology Policy (STI policy) aims to "mobilise funds for engaging in international research collaboration" (Second Science, Technology and Innovation Policy of Zimbabwe, 2012, p. 14).

Overally, with the exception of the humanities, the highest number of authors responsible for article production in Zimbabwe had an international affiliation. This indicates that production of Zimbabwean articles is largely dominated by researchers from outside Zimbabwe. To explain why African science is a largely dominated by international researchers, Ishengoma (2016) and Pouris (2017) argued that many of Africa's R&D organisations, specifically institutions of higher education, rely on foreign funding for their R&D performance. This funding is often linked to a northern based principal investigator (e.g. USA or EU), who by default is indicated as an international co-author of papers emanating from this research (CREST, 2019). In their study, Hedt-Gauthier et al. (2019) showed that international researchers take first place author positions in African health research. Hedt-Gauthier and his team found that collaborating with researchers in high-income countries decreased local representation, particularly in first and last positions; in other words, in terms of authorship in health research, African scientists did not take up leadership positions. The authors attributed this to the fact that compared to researchers in low-income countries, those in high-income countries have technical advantages; greater economic and academic resources, including extensive institutional infrastructure to lead project administration; and stronger research networks, including greater representation on journal editorial boards. Considering this, perhaps what is needed in Africa are robust measures aimed at mobilising resources for research. Currently, although African countries have committed to investing in R&D and to allocate 1% of their expenditure to R&D, most countries, Zimbabwe included, struggle to meet this goal (Mouton, 2018).

In conclusion, it can be argued that the exploration of different units of analysis such as author-level datasets aids in the provision of more comprehensive results. The author level analysis of researchers in Zimbabwe allowed the identification of the country's research workforce and the sectors and fields were that workforce is concentrated. The analysis showed that there is a huge overlap of researchers classified in more than one sector and in more than one field. This could mean that the same researchers were likely responsible for the production of articles in the different sectors and fields. The analysis also showed the research output and research collaboration patterns of the most productive researchers in the country. Such findings apply in the country's research policy context.

11.5 Addressing research objective 4

> *Objective 4: To introduce a focus on INOs in bibliometric studies by developing a new classification framework of authorship types that accommodates the phenomenon of INOs as a form of international participation, and applying it to Zimbabwe's research.*

The study introduced a new measure of international research participation in Africa's research by focusing on what is reffered to in this study as 'international national organisations' (INOs). As explained in the previous chapters, INOs are international organisations or initiatives of international organisations (or sets of organisations) that use African country addresses in their publications. The organisations tend to be adapted to host countries by supporting the research goals and research agendas of those countries. While they appear to be national organisations, they are in fact international organisations. In bibliometric studies of African countries, INOs can be coded erroneously as national organisations as they do not report their international addresses in publications but rather the addresses of African host countries. Most of these INOs are bound by treaties and arrangements to work on issues of common issues. Although there are commonly seen as international organisations, when they conduct research, they use host country addresses, contributing to the research output of the host country.

Contribution of INOs to research in Zimbabwe during the period 1980–2016

An analysis of Zimbabwean-authored articles in the Scopus and WoS databases, for the period 1980-2016, showed that the total number of articles with at least one INO address was equivalent to 11% of the country's total article output. Despite having gone through periods of turmoil and international isolation, international participation as demonstrated through international co-authorship and INOs, consistently increased across the four socio-political periods. In 2006, the contribution by the INO sector to the total article output in the country reached a peak of 20%. One explanation for this 'anomaly' could be that INOs have long standing partnerships with international organisations. It is likely that INOs continued to receive funding for research from international organisations even though the country was under international isolation. It is also likely that fields such as health sciences are immune to political challenges prevailing in countries. As already highlighted in the previous sections, researchers in the health sciences were able to withstand some of the country's socio-political challenges due to the availability of international funding and partnerships (Hodgkinson &

Pasirayi, 2015). Agricultural research became dominated by INOs such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) with its headquarters based in India; the International Institute of Tropical Agriculture (IITA) with its headquarters in Nigeria; the International Maize and Wheat Improvement Center (CIMMYT) based in Mexico; and the International Center for Tropical Agriculture (CIAT) based in Colombia.

The largest share of articles with an INO address were in agricultural sciences, followed by those in health sciences, natural sciences, and social sciences, in that particular order. Out of the four types of INOs (i.e. intergovernmental organisations; international non-governmental organisations (NGOs); international research organisations, research networks, or global research partnerships; and international businesses), international research organisations accounted for the largest share of articles. The International Maize and Wheat Improvement Center (CIMMYT) was the most frequently counted INO in the country. One finding made in the study is that CIMMYT publishes in journals with multiple subject categories. It produced articles in the agricultural, health, natural and social sciences. A follow up study to establish if the same or different authors were publishing across all fields would be required.

Application of the classification framework of 20 authorship types

A classification framework for authorship types was developed as part of this study. Application of this framework to Zimbabwe's fields showed that, during the early years of independence, research was predominantly produced by one or more authors from a single national institution. However, as time passed, the country's research became dominated by international co-authorship together with the participation of INOs. One explanation for this trend, as already mentioned before is that, at the time of the economic meltdown during the period 1998–2008, most skilled professionals and researchers had left the country. The human capital base in Zimbabwe had "been eroded to the point where effective research and teaching was barely possible" Mouton et al. (2008, p. 250). Hence, the few remaining researchers who wanted to pursue a research agenda, as well as newly trained researchers returning from scholarships abroad, could only do so through international collaboration, which included participation by INOs. Additionally, faced with limited funding for research, researchers in the country became increasingly dependent on international authors for resources, and thus pursued all possible avenues of international networking.

After analysing the intersection of the two kinds of international participation in the respective fields, (i.e. international co-authorship and participation of INOs), in the four socio-political periods it was found that there was an increase in the percentage of articles produced through international co-authorship and in the percentage of articles produced through both international co-authorship and INOs. It was found that participation by INOs without international co-authorship also being simultaneously present was minimal. An increase in international co-authorship was found to coincide with an increase in INOs. The link between international co-authorship and INOs thus requires further investigating. It could be a matter of multiple affiliations, where some of the international co-authors of Zimbabwean articles – reflecting an international organisation (IO) – are associated with an INO in Zimbabwe. In such cases, it can be questioned whether such articles are 'true' Zimbabwean articles.

In conclusion, despite having gone through international isolation, participation of international partners in Zimbabwe's research continued. Although the finding of increased international collaboration in Africa's research is well established in the literature (e.g. Adams et al. 2014; Mouton and Blanckenberg 2018), the observation that it coincides with participation by INOs is not. The framework of authorship types developed in the study. can also be used in other bibliometric studies of research collaboration to identify authors with dual international affiliations.

11.6 Conclusion

The study provided an in-depth analysis of research production and research collaboration in Zimbabwe. It profiled the research production and research collaboration trends and patterns of Zimbabwean organisations in the different national sectors and fields and also within four socio-political periods. The study showed the value of applying context in bibliometric studies of research collaboration. As research collaboration does not occur in a vacuum, but is best understood within the context which research is conducted, including social, institutional, and technical environments.

The study introduced the phenomenon of 'International national organisations' (INOs) which represents a new form of measuring international participation in Africa's research. It developed a new classification framework of authorship types that accommodates the phenomenon of INOs as a form of international participation. Not only does that framework accommodate the phenomenon of INOs but it can also be used in other bibliometric studies of research collaboration to identify authors with dual international affiliations. The study integrated and unified two mainstream bibliographic databases (Scopus and WoS), to create a new database of Zimbabwean articles, it supplemented the database with articles from the (NRDZ). The latter is a national, non-mainstream data source.

11.7 Recommendations

The following recommendations were compiled

- The study relied on two mainstream databases (i.e. WoS and Scopus) for the analysis of research production and research collaboration in Zimbabwe. Although combining Scopus and WoS data provided a comprehensive coverage of Zimbabwean articles, it is noted, as reported in the literature, that mainstream databases such as WoS and Scopus are (i) not affordable and (ii) not easily accessible, especially for developing countries. Universities in Zimbabwe most probably do not have access to the WoS and Scopus databases. What this means is that people within the country do not use the latter sources and only those outside Zimbabwe are able to utilise the databases to reflect on the country's scientific production. What is needed is a compilation of records of what researchers in the country publish.

  Therefore, firstly, I recommend a national system where details and records of all articles (e.g. title of research articles, author names, affiliation of authors and even abstracts of articles) produced in the country are uploaded. Even though people do not have access to WoS and Scopus, at least they can get to know what articles are in the mainstream databases. Although the National Research Database of Zimbabwe (NRDZ) covers the country's 'public domain research', the repository cannot index all journals. The reason for this is that not all journals permit self-archiving of published research in repositories.

  Secondly, I also recommend the use of national journals to reflect on Zimbabwe's scientific production. The status of these national journals has to be clear and the journals must publish articles regularly. These journals must also have arrangements with national repositories so that articles may be uploaded in the repositories. Currently, most national journals in the country are either irregular or ceased publishing. Appendix 15 shows a compilation of national journals currently present in Zimbabwe. It can be seen, as shown in the Appendix, that some of the journals such as the *Southern Africa Journal of Education, Science and Technology* published by Bindura University of Science Education had its first issue in 2006 but has had irregular issues since 2008. Furthermore, I recommend that the country considers establishing more national journals.

- The study used a third data source (NRDZ) to reflect on the value of using a national research database as a bibliometric data source. However, the database did not make a significant contribution to articles already indexed in the WoS and Scopus databases. One reason for this, among other factors, as already mentioned above could be the fact that not all journals permit self-archiving of published research in repositories. Although some Open Access (OA) models permit self-archiving of published material, such models require authors to pay publication fees for articles to appear as OA in journals.

  Therefore, I recommend that research institutions in the country provide researchers with the necessary financial resources for ensuring that research articles appear in OA journals in order for such articles to be uploaded to the NRDZ. I also recommend that researchers in the country be made aware of the national repository. Perhaps the low coverage of Zimbabwe's articles in the NRDZ could be a result of a lack of awareness.

- The study found that the majority (27%) of 'articles' indexed in the NRDZ were articles in 'questionable journals'. Questionable journals are journals that prioritise money at the expense of scholarship. Such journals charge exorbitant amounts for publishing articles. The journals have quick peer review process and usually spam emails to solicit manuscripts. Although there are many debates surrounding publishing articles in questionable journals, the journals do not increase the visibility of researchers.

  I recommend a list of approved journals where researchers in the country can publish articles in. The list can be compiled by a research governing body in the country (i.e. the Research Council of Zimbabwe) and researchers can be encouraged to publish articles in the country's approved list of journals.

- The study identified lack of incentives and rewards as one of the reasons why some academics in Zimbabwe do not produce articles and why they do not engage in collaborative research.

  Therefore, to encourage the production of more articles and the production of articles through collaboration, I recommend a system where a monetary value or some incentive is attached to the type of authorship in which articles are generated.

- The study also identified too much work overload as a reason for not producing articles and for not engaging in research collaboration. I recommend an investment in human resources to increase the number of researchers in the country. If it is not feasible to attract, train and employ more researchers, then additional teaching staff would need to be employed so that some of the existing teaching staff, especially those with the greatest research potential, can have more time for research (thereby increasing the FTEs devoted to research).

- The study found that the US and the UK were the top international collaborators of Zimbabwe. The reason for the prominence of these countries in Zimbabwe's research could be a result of health and agricultural networks. South Africa, the UK and the US constituted approximately 77% of all foreign collaboration between 2009 and 2016. There is a need for the expansion of regional and international collaboration. I also recommend an expansion of the current partnerships that go beyond the agricultural and health sciences fields.

11.7 Future research

The study identified several areas for future research. These include:

- The use of qualitative methods to investigate in more detail the different types of research production and research collaboration in Zimbabwe.
- Investigating the nature and context of the overlap between research collaboration and research co-authorship, and on how such insight would inform the understanding of research collaboration.
- The use of author-level bibliometric analysis to investigate institutional and sector 'overlaps' in Zimbabwe's research workforce. It emerged in the study that several authors were affiliated to more than one institution and also classified in more than one field.
- The use of co-authorship networks to visualise the local and networks of Zimbabwean researchers.
- Investigating the link between international co-authorship and INOs. It emerged in the study that participation by INOs without international co-authorship also being simultaneously present was minimal. This could be a matter of multiple affiliations, where some of the international co-authors of Zimbabwean articles – reflecting an international organisation (IO) – are associated with an INO in Zimbabwe.

- Perfoming topic modelling to identify clusters of research topics and to determine how topics differ according to the involvement of different national and international organisations and different national sectors.

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APPENDIX 1

Survey of research collaboration and related activities in Zimbabwe

Section A: Reflections on research collaboration

1. How regularly do you engage in research collaboration? (Research collaboration refers to joint research and/ or joint publications.)

Always	1
Often	2
Sometimes	3
Seldom	4
Never collaborate in research	5

- If your answer is "*I always/often/sometimes collaborate in research*" – Ignore Question 2 and go to Question 3.
- If your answer is "*I seldom/never collaborate in research*" – Answer only Question 2 and go straight to Section B.

2. What is the single, most important reason why you seldom/never engage in research collaboration? (Please be as specific as possible.)

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3. How regularly do you collaborate, either in joint research or through joint publications, with the following individuals?

	Always	Often	Some-times	Seldom	Never
Individuals from my own organisation in Zimbabwe	1	2	3	4	5
Individuals from other organisations in Zimbabwe	1	2	3	4	5
Individuals in South Africa	1	2	3	4	5
Individuals in the rest of Africa (South Africa excluded)	1	2	3	4	5
Individuals in Europe	1	2	3	4	5
Individuals in the USA	1	2	3	4	5
Individuals in Asia	1	2	3	4	5
Individuals elsewhere in the world	1	2	3	4	5

4. For a typical research project, what is the average size of your research group? (A 'research group' comprises those responsible for one or more of the main elements of the research, including postgraduate students. Please include yourself in the size estimates provided below.)

2 individuals	1
3 individuals	2
4 individuals	3
5 individuals	4
6 to 10 individuals	5
More than 10 individuals	6

5. What is the single, most important reason why you engage in research collaboration? (Please be as specific as possible.)

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6. When choosing a research collaborator, to what extent do you consider the following aspects as important?

	Very important	Moderately important	Slightly important	Not at all important
Collaborator has unique skills/expertise	1	2	3	4
Collaborator has skills/knowledge that complement my own	1	2	3	4
Collaborator has access to special data	1	2	3	4
Collaborator has access to special equipment	1	2	3	4
Collaborator has access to funds	1	2	3	4
Collaborator has the right profile or networks to attract funding	1	2	3	4
Collaborator has strong work ethics	1	2	3	4
Collaborator has a good research reputation	1	2	3	4
Collaborator gives credit where it is due	1	2	3	4
Collaborator and I have the same nationality	1	2	3	4
Collaborator speaks my language	1	2	3	4
Collaborator is of the same sex	1	2	3	4
Collaborator and I are similar in age	1	2	3	4

- *If your answer to "Collaborator has unique skills" is either option 1 or option 2 – Answer Question 7*
- *If your answer to "Collaborator has unique skills" is either option 3 or option 4 – Ignore Question 7 and go to Question 8*

7. Which unique skills/expertise of a collaborator do you consider important? (Select ALL that apply.)

Proposal writing	1
Resourceful in terms of ideas	2
Critical reflection	3
Fund raising	4
Networking	5
Software programming	6
Data collection	7
Statistical data analysis	8
Qualitative data analysis	9
Report writing	10
Article writing	11
Other Specify:	12

8. The following could be experienced as challenges when engaging in research collaboration. How serious a problem are these in <u>your own research collaborations</u>?

	A major problem	A moderate problem	A minor problem	No problem at all	Not applicable
Roles of collaborators not well defined	1	2	3	4	5
Activities of collaborators not well aligned	1	2	3	4	5
Collaborators not delivering work when and/or as agreed	1	2	3	4	5
Diverse national cultures in the collaboration	1	2	3	4	5
Gender stereotyping in the collaboration	1	2	3	4	5
Collaborators in different career stages	1	2	3	4	5
Disputes about authorship	1	2	3	4	5
Challenges related to leadership and control	1	2	3	4	5
Being ‘micro managed’ by others in the collaboration	1	2	3	4	5
Breach of information security	1	2	3	4	5
Collaborators not sharing relevant information	1	2	3	4	5
Diverse personality types of collaborators	1	2	3	4	5
Collaborators acting only in their own interests without considering others	1	2	3	4	5
Diverse institutional cultures in the collaboration	1	2	3	4	5

Large geographic distances between collaborators	1	2	3	4	5
Collaborators not being trustworthy	1	2	3	4	5
Collaborators publishing the group's work without informing others	1	2	3	4	5
Collaborators using or distributing the research data without informing others	1	2	3	4	5
Diverse disciplinary cultures in the collaboration	1	2	3	4	5
Lack of gender diversity in the collaboration	1	2	3	4	5
Exploitation of junior researchers and/or students in the collaboration	1	2	3	4	5
Lack of recognition of technical staff in the collaboration	1	2	3	4	5
Lack of recognition of administrative staff in the collaboration	1	2	3	4	5
Collaborators insisting on co-authorship without having made any contributions	1	2	3	4	5

9. Please think about <u>one specific research collaboration</u> that you engaged in during the last five years. How did that specific collaboration come about? (Select ALL that apply.)

Collaboration was initiated by a mutual acquaintance	1
Collaboration was initiated by a funding agency	2
Collaboration resulted from a partnership between our respective institutions	3
Collaboration resulted from us having a student-supervisor relationship	4
Collaboration resulted from us having a work relationship	5
Collaboration resulted from us having a personal relationship	6
Collaboration resulted from us having met at a conference/workshop/seminar	7
Collaboration resulted from us working in the same disciplinary field	8
Collaboration resulted from us working in different but complementing disciplinary fields	9
Collaboration resulted from us having worked in the same organisation	10
Collaboration was requested by someone in management/administration	11
Other reason (Specify: ……………………………..…………………………………………………….)	12

Section B: Article co-authorship

10. Which one of the following best describes your article-authorship practices? (Select ONE only.)

I mostly write single-authored articles	1
I mostly write co-authored articles	2
I write both single- and co-authored articles (about evenly divided)	3

- *If your answer is option 1 – Ignore Questions 11 to 17 and go to Question 18.*
- *If your answer is either option 2 or option 3 – Answer Question 11 and continue with the rest.*

11. Have you ever experienced an authorship-related dispute (e.g. inclusion as a co-author, order of names etc.)? (Select ONE only.)

Yes	1
No	2

- *If your answer is "Yes" – Answer Question 12 and continue with the rest.*
- *If your answer is "No" – Ignore Questions 12, 13 and 14 and go to Question 15 and continue with the rest.*

12. What was the dispute / were the disputes about? (Select ALL that apply.)

Which collaborators to list as the authors of an article	1
Which collaborators to mention in the acknowledgement of an article	2
The order that author names should be reflected in an article	3
How to distribute authorship across different articles	4
Other (Specify: ……………………………………………………………………………)	5

13. Did you resolve the dispute(s)?

Yes	1
No	2

14. If yes, how did you resolve the disputes(s)? / If no, why could you not resolve the dispute(s)?

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15. In your experience, how is co-authorship of articles most commonly established?

	Yes	No
We follow a set of compulsory rules	1	2
We follow a set of advisory guidelines	1	2
We follow common practice in our field	1	2
Co-authorship is informally negotiated among members of the research group on a case-by-case basis	1	2
Other (Specify: ……………………………………………………………………………………..)		

16. In your opinion/experience, what would be the best/most appropriate stage to discuss issues of co-authorship of articles? (Select ALL that apply.)

During conceptualisation of the research	1
During proposal writing	2
During finalisation of a research contract/agreement	3
During development of a data management plan	4
During data collection	5
During data analysis	6
During article writing	7
During submission of an article to a journal	8
Other (Specify: ……………………..…………………………………………….)	9

17. Please explain your answer to the question above.

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Section C: Data ownership and data sharing in research

18. In the <u>past five years,</u> have you participated in any of the following activities?

	Yes	No
Shared your data on a repository	1	2
Shared your data with one or more other researchers/scientists	1	2
Used data that belongs to someone else	1	2
Used a student or research assistant or junior researcher to collect data for your own research	1	2
Collected data for the research of a more senior researcher	1	2

19. In the <u>past five years</u>, have you ever experienced <u>disputes regarding data ownership and sharing</u> in a project?

Yes	1
No	2

- *If your answer is "Yes" to any of the above – Answer Question 20 and continue*

- *If your answer is "No" to all of the above – Ignore Questions 20, 21, 22 and go to Question 24 and continue.*

20. With whom did you experience disputes regarding data ownership and sharing in a project? (Select ALL that apply.)

	Yes	**No**
Members of your research group	1	2
A university or other academic institution	1	2
A research organisation (not university)	1	2
Government or a government-based organisation	1	2
A private company	1	2
A journal	1	2
Other (Specify: ……………………………………………………………………………………..)		

21. What was the dispute / were the disputes about?

…………………………………………………………………………………………………

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22. Did you resolve the dispute(s)?

Yes	1
No	2

23. If yes, how did you resolve the disputes(s)? / If no, why could you not resolve the dispute(s)?

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24. In your experience, how is data ownership most commonly established?

	Yes	**No**
We follow a set of compulsory rules	1	2
We follow a set of advisory guidelines	1	2
We follow common practice in our field	1	2
Data ownership is informally negotiated among members of the research group on a case-by-case basis	1	2
Other (Specify: ……………………………………………………………………………………..)		

25. In your opinion/experience, what would be the best/most appropriate stage to discuss issues of data ownership? (Select ALL that apply.)

During conceptualisation of the research	1
During proposal writing	2
During finalisation of a research contract/agreement	3
During development of a data management plan	4
During data collection	5
During data analysis	6
During feedback (of results) to the funder/contracting agency	7
During preparations for data preservation	8
Upon depositing of data in an institutional or subject data repository	9
Upon leaving a research institution for employment elsewhere	10
Other (Specify: ………………….……………………………………………….)	11

26. How big a challenge is data ownership in your research field?

A major challenge	1
A moderate challenge	2
A minor challenge	3
No challenge at all	4

27. Please explain your answer to the question above.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

Section D: Demographics

28. What is your gender?

Female	1
Male	2

29. Where do you currently work?

University	1
Government organisation	2
Public research organisation (not university or government)	3
Intergovernmental organisation (e.g. World Bank, UN, UNDP)	4
Non-governmental organisation	5
Industry/business	6
Other (Specify: ……………………………………………………………….……..)	7

30. What is your area of research (e.g. agriculture, medicine, aquaculture, anthropology, psychiatry)?

…………………………………………………………………………………………………

31. At this point in time, what is/are your country affiliation/s (e.g. Zimbabwe)?

…………………………………………………………………………………………………

32. How would you classify yourself in terms of research experience?

Not a researcher (e.g. technician, administrator)	1
First stage researcher (not yet a PhD or still busy with a PhD)	2
Recognised researcher (PhD holder or equivalent who is not yet fully independent)	3
Established researcher (researcher who has developed a level of independence)	4
Leading researcher (researcher leading his/her research area or field)	5

33. What is your highest academic qualification?

Doctoral or equivalent	1
Master or equivalent	2
Other (Specify: …………………………………………………..)	3

34. In what year did you obtain your highest academic qualification?

……………………………………

35. In which country did you obtain your highest academic qualification?

……………………………………

36. In what year were you born?

……………………………………

THE END

Thank you for your time and effort

APPENDIX 2

Types of research collaboration in Zimbabwe by broad field and by socio-political periods

Field by period	National co-authorship only		International co- authorship only		Both national and international co- authorship	
	Count	%	Count	%	Count	%
AS: 1980-1990 (n=195)	117	60%	69	35%	9	5%
AS: 1991-1997 (n=372)	192	52%	140	38%	40	11%
AS: 1998-2008 (n=725)	186	26%	409	56%	130	18%
AS: 2009-2016 (n=547)	167	31%	206	38%	174	32%
NS: 1980-1990 (n=262)	141	54%	104	40%	17	6%
NS: 1991-1997 (n=454)	213	47%	205	45%	36	8%
NS: 1998-2008 (n=938)	241	26%	534	57%	163	17%
NS: 2009-2016 (n=1141)	296	26%	475	42%	370	32%
HS: 1980-1990 (n=596)	477	80%	99	17%	20	3%
HS: 1991-1997 (n=757)	420	55%	261	34%	76	10%
HS: 1998-2008 (n=1 124)	299	26%	516	46%	309	27%
HS: 2009-2016 (n=1 249)	164	13%	515	41%	570	46%
SS: 1980-1990 (n=69)	49	71%	18	26%	2	3%
SS: 1991-1997(n=143)	66	46%	66	46%	11	8%
SS: 1998-2008 (n=262)	47	18%	169	65%	46	18%
SS: 2009-2016 (n=535)	144	27%	254	47%	137	26%
HU: 1980-1990 (n=12)	9	75%	3	25%	0	0%
HU: 1991-1997 (n=7)	2	29%	4	57%	1	14%
HU: 1998-2008 (n=27)	11	41%	14	52%	2	7%
HU: 2009-2016 (n=121)	40	33%	66	55%	15	12%
ET: 1980-1990 (n=13)	7	54%	6	46%	0	0%
ET: 1991-1997 (n=60)	24	48%	29	48%	2	3%
ET: 1998-2008 (n=132)	41	31%	74	56%	17	13%
ET: 2009-2016 (n=102)	34	33%	43	42%	25	25%

Note: AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

APPENDIX 3

Types of research collaboration in Zimbabawe by national sector and by socio-political periods

Sector by period	National co-authorship only		International co-authorship only		Both national and international co-authorship	
	Count	%	Count	%	Count	%
University: 1980-1990 (n=614)	459	75%	127	21%	28	5%
University: 1991-1997 (n=1 009)	566	56%	338	33%	105	10%
University: 1998-2008 (n=1 841)	615	33%	753	41%	473	26%
University: 2009-2016 (n=2 199)	679	31%	762	35%	758	34%
Government: 1980-1990 (n=381)	272	71%	97	25%	12	3%
Government: 1991-1997 (n=455)	244	54%	154	34%	57	13%
Government: 1998-2008 (n=608)	172	28%	242	40%	194	32%
Government: 2009-2016 (n=619)	139	22%	153	25%	327	53%
NGO: 1980-1990 (n=14)	6	43%	2	14%	6	43%
NGO: 1991-1997 (n=36)	19	53%	7	19%	10	28%
NGO: 1998-2008 (n=161)	18	11%	71	44%	72	45%
NGO: 2009-2016 (n=374)	24	6%	103	28%	247	66%
INO: 1980-1990 (n=44)	21	48%	15	34%	8	18%
INO: 1991-1997 (n=98)	33	34%	51	52%	14	14%
INO: 1998-2008 (n=399)	56	14%	254	64%	89	22%
INO: 2009-2016 (n=542)	78	14%	207	38%	257	47%
Other: 1980-1990 (n=20)	16	80%	3	15%	1	5%
Other: 1991-1997 (n=32)	14	42%	15	48%	3	9%
Other: 1998-2008 (n=110)	29	26%	47	43%	34	31%
Other: 2009-2016 (n=192)	37	19%	77	40%	78	41%

APPENDIX 4

Types of national research collaboration in Zimbabwe by broad field and by socio-political periods

Field by period	Intra-institutional co-authorship only		Inter-institutional co-authorship only		Both intra and inter-institutional co-authorship	
	Count	%	Count	%	Count	%
AS: 1980-1990 (n=126)	109	87%	12	10%	5	4%
AS: 1991-1997 (n=232)	189	81%	33	14%	10	4%
AS: 1998-2008 (n=316)	191	60%	90	28%	35	11%
AS: 2009-2016 (n=341)	184	54%	34	10%	123	36%
NS: 1980-1990 (n=158)	142	90%	11	7%	5	3%
NS: 1991-1997 (n=249)	218	88%	25	10%	6	2%
NS: 1998-2008 (n=404)	241	60%	122	30%	41	10%
NS: 2009-2016 (n=666)	355	53%	80	12%	231	35%
HS: 1980-1990 (n=497)	466	94%	20	4%	11	2%
HS: 1991-1997 (n=496)	408	82%	48	10%	40	8%
HS: 1998-2008 (n=608)	376	62%	123	20%	109	18%
HS: 2009-2016 (n=734)	389	53%	84	11%	261	36%
SS: 1980-1990 (n=51)	49	96%	2	4%	0	0%
SS: 1991-1997 (n=77)	68	88%	6	8%	3	4%
SS: 1998-2008 (n=93)	56	60%	18	19%	19	20%
SS: 2009-2016 (n=281)	195	69%	32	11%	54	19%
HU: 1980-1990 (n=9)	9	100%	0	0%	0	0%
HU: 1991-1997 (n=3)	2	67%	1	33%	0	0%
HU: 1998-2008 (n=13)	12	92%	1	8%	0	0%
HU: 2009-2016 (n=55)	36	65%	13	24%	6	11%
ET: 1980-1990 (n=7)	7	100%	0	0%	0	0%
ET: 1991-1997 (n=31)	30	97%	1	3%	0	0%
ET: 1998-2008 (n=58)	32	55%	23	40%	3	5%
ET: 2009-2016 (n=59)	39	66%	10	17%	10	17%

Note: AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

APPENDIX 5

Types of national research collaboration in Zimbabawe by sector and by socio-political periods

Sector by period	Intra-institutional co-authorship only		Inter-institutional co-authorship only		Both intra and inter-institutional co-authorship	
	Count	%	Count	%	Count	%
University: 1980-1990 (n=487)	439	90%	32	7%	16	3%
University: 1991-1997 (n=671)	557	83%	69	10%	45	7%
University: 1998-2008 (n=1 088)	657	60%	262	24%	169	16%
University: 2009-2016 (n=1 437)	772	54%	167	12%	498	35%
Government: 1980-1990 (n=284)	238	84%	34	12%	12	4%
Government: 1991-1997 (n=301)	181	60%	79	26%	41	14%
Government: 1998-2008 (n=366)	67	18%	196	54%	103	28%
Government: 2009-2016 (n=466)	49	11%	102	22%	315	68%
NGO: 1980-1990 (n=12)	4	33%	3	25%	5	42%
NGO: 1991-1997 (n=29)	3	10%	16	55%	10	34%
NGO: 1998-2008 (n=90)	17	19%	48	53%	25	28%
NGO: 2009-2016 (n=271)	91	34%	23	8%	157	58%
INO: 1980-1990 (n=29)	15	52%	10	34%	4	14%
INO: 1991-1997 (n=47)	32	68%	13	28%	2	4%
INO: 1998-2008 (n=145)	36	25%	72	50%	37	26%
INO: 2009-2016 (n=335)	87	26%	54	16%	194	58%
Other: 1980-1990 (n=17)	14	82%	3	18%	0	0%
Other: 1991-1997 (n=17)	8	47%	6	35%	3	18%
Other: 1998-2008 (n=63)	12	19%	33	52%	18	29%
Other: 2009-2016 (n=115)	26	23%	32	28%	57	50%

APPENDIX 6

Types of international collaboration in Zimbabwe by broad field and by socio-political periods

Sector by period	Co-authorship with rest of Africa only		Co-authorship with rest of world only		Co-authorship with rest of Africa and rest of world	
	Count	%	Count	%	Count	%
AS: 1980-1990 (n=78)	17	22%	57	73%	4	5%
AS: 1991-1997 (n=180)	25	14%	136	76%	19	11%
AS: 1998-2008 (n=539)	116	22%	304	56%	119	22%
AS: 2009-2016 (n=380)	143	38%	114	30%	123	32%
NS: 1980-1990 (n=121)	30	25%	81	67%	10	8%
NS: 1991-1997 (n=241)	31	13%	186	77%	24	10%
NS: 1998-2008 (n=697)	153	22%	420	60%	124	18%
NS: 2009-2016 (n=845)	241	29%	316	37%	288	34%
HS: 1980-1990 (n=119)	24	20%	86	72%	9	8%
HS: 1991-1997 (n=337)	45	13%	258	77%	34	10%
HS: 1998-2008 (n=825)	79	10%	559	68%	187	23%
HS: 2009-2016 (n=1 085)	110	10%	443	41%	532	49%
SS: 1980-1990 (n=20)	2	10%	16	80%	2	10%
SS: 1991-1997 (n=77)	7	9%	68	88%	2	3%
SS: 1998-2008 (n=215)	29	13%	153	71%	33	15%
SS: 2009-2016 (n=391)	185	47%	135	35%	71	18%
HU: 1980-1990 (n=3)	0	0%	2	67%	1	33%
HU: 1991-1997 (=5)	1	20%	3	60%	1	20%
HU: 1998-2008 (n=16)	2	13%	12	75%	2	13%
HU: 2009-2016 (n=81)	58	72%	11	14%	12	15%
ET: 1980-1990 (n=6)	1	17%	5	83%	0	0%
ET: 1991-1997 (n=31)	5	16%	26	84%	0	0%
ET: 1998-2008 (n=91)	24	26%	61	67%	6	7%
ET: 2009-2016 (n=68)	27	40%	33	49%	8	12%

Note: AS=agricultural sciences; NS=natural sciences; HS=health sciences; SS=social sciences; HU=humanities; ET=engineering and technologies

APPENDIX 7

Types of international collaboration in Zimbabwe by national sector and by socio-political periods.

Sector by period	Co-authorship with rest of Africa only		Co-authorship with rest of world only		Co-authorship with rest of Africa and rest of world	
	Count	%	Count	%	Count	%
University: 1980-1990 (n=155)	25	16%	118	76%	12	8%
University: 1991-1997 (n=443)	57	13%	353	80%	33	7%
University: 1998-2008 (n=1 226)	233	19%	813	66%	180	15%
University: 2009-2016 (n=1 520)	509	33%	528	35%	483	32%
Government: 1980-1990 (n=109)	26	24%	78	72%	5	5%
Government: 1991-1997 (n=211)	25	12%	163	77%	23	11%
Government: 1998-2008 (n=436)	67	15%	306	70%	63	14%
Government: 2009-2016 (n=480)	86	18%	256	53%	138	29%
NGO: 1980-1990 (n=8)	3	38%	5	63%	0	0%
NGO: 1991-1997 (n=17)	0	0%	13	76%	4	24%
NGO: 1998-2008 (n=143)	10	7%	94	66%	39	27%
NGO: 2009-2016 (n=350)	33	9%	219	63%	98	28%
INO: 1980-1990 (n=23)	2	9%	19	83%	2	9%
INO: 1991-1997 (n=65)	7	11%	46	71%	12	18%
INO: 1998-2008 (n=343)	67	20%	158	46%	118	34%
INO: 2009-2016 (n=464)	80	17%	155	33%	229	49%
Other: 1980-1990 (n=4)	3	75%	1	25%	0	0%
Other: 1991-1997 (n=18)	1	6%	12	67%	5	28%
Other: 1998-2008 (n=81)	23	28%	40	49%	18	22%
Other: 2009-2016 (n=155)	32	21%	52	34%	71	46%

APPENDIX 8

List of Zimbabwean organisations within the Ministry of Health and Child Care, contributing to research in health sciences (1980-2016)

Organisation	1980-1990 (n=225)	1991-1997 (n=209)	1998-2008 (n= 223)	2009-2016 (n=301)
Ministry of Health and Child Care	18	34	45	160
National Institute of Health Research	72	59	87	60
Harare Central Hospital	47	17	11	18
Parirenyatwa Central Hospital	14	27	36	18
Mpilo Central Hospital	36	29	13	15
National AIDS Council of Zimbabwe	--	--	--	15
Medical Research Council of Zimbabwe	--	--	1	12
Midlands Province, Provincial Medical Directorate	--	1	2	2
Zimbabwe National Family Planning Council	1	1	1	2
Murehwa District Hospital	--	1	1	2
Pharmacovigilance Centre - Medicines Control Authority of Zimbabwe		1	1	2
Chitungwiza General Hospital	1	1	1	1
Murewa District Hospital	--		--	1
Greenwood Park Eye Centre	--	--	--	1
United Bulawayo Hospitals	1	15	11	1
Gweru Provincial Hospital	20	8	1	1
Mutare Provincial Hospital	1	2	1	1
Mashonaland East Province, Provincial Medical Directorate	--	1	1	1
Mashonaland West Province, Provincial Medical Directorate	--	--	1	1
Mashonaland Central Province, Provincial Medical Directorate	--	--	--	1
Gwanda Provincial Hospital	--	-	--	1
Pharmacist Council of Zimbabwe				1
De Beers Research Laboratory	1	1	2	--
Marondera Provincial Hospital	2	-	1	--
Matebeleland North Province, Provincial Medical Directorate	1	1	1	--
Bindura Provincial Hospital	1	1	1	--
Ingutsheni Hospital	1		1	--
National Rehabilitation Centre			1	
Masvingo Province, Provincial Medical Directorate	--	1	1	--

Organisation	1980-1990 (n=225)	1991-1997 (n=209)	1998-2008 (n= 223)	2009-2016 (n=301)
National Drug and Therapeutics Policy Advisory Committee (NDTPAC)	--	1	1	--
Chinhoyi Provincial Hospital	--	1	1	--
Masvingo Provincial Hospital	--	1	1	--
Beatrice Road Infectious Diseases Hospital	1	--	1	--
Chimanimani Hospital	1	1	--	--
Binga District Hospital		1	--	--
Chinhoyi Province, Provincial Medical Directorate	--	1	--	--
Chipinge District Hospital	--	1		--
Chivhu General Hospital	--	1		--
Council for the Blind	--	1		--
Karoi District Hospital	--	1	--	--
Manicaland Province, Provincial Medical Directorate	--	1	--	--
Mutare Province, Provincial Medical Directorate	--	1	--	--
Sakubva District Hospital	--	1		
Rusape General Hospital	1	--	--	--

APPENDIX 9

List of organisations within the Ministry of Lands, Agriculture and Rural Settlement, contributing to research in natural sciences (1980-2016)

Organisation	1980-1990 (n=94)	1991-1997 (n=86)	1998-2008 (n=93)	2009-2016 (n=27)
Livestock and Veterinary	52	54	35	4
Department of Research and Specialist Services (DRSS)	30	22	47	17
Tobacco Research Board	6	5	4	5
Agricultural Bank of Zimbabwe	-	-	-	2
Department of Agricultural Technical and Extension Services (AGRITEX)	-	2	2	-
Agricultural and Rural Development Authority (ARDA)	2	-	-	-
Institute of Agricultural Engineering	-	1	2	-
Pig Industry Board	2	2	-	-
Gwebi College of Agriculture	1	-	-	-
Ministry of Lands, Agriculture and Rural Settlement	1	-	-	-

APPENDIX 10

List of Zimbabwean organisations within the Ministry of Health and Child Care, contributing to research in natural sciences (1980-2016)

Organisation	1980-1990 (n=11)	1991-1997 (n=12)	1998-2008 (n=26)	2009-2016 (n=65)
Ministry of Health and Child Care	2	-	3	41
De Beers Research Laboratory	--	2	3	--
Gweru Provincial Hospital	1	--	--	--
Harare Central Hospital	--	--	2	5
Masvingo Province, Provincial Medical Directorate	--	--	--	1
Matabeleland South Province, Provincial Medical Directorate	--	--	1	--
Matebeleland North Province, Provincial Medical Directorate	--	--	--	1
Medical Research Council of Zimbabwe	--	--	--	5
Midlands Province, Provincial Medical Directorate	--	--	--	1
Mpilo Central Hospital	--	1	--	1
Murehwa District Hospital	--	--	--	1
National AIDS Council of Zimbabwe	--	--	--	2
National Institute of Health Research	6	9	14	9
Parirenyatwa Central Hospital	2	--	4	3
United Bulawayo Hospitals	--	--	1	--
Zimbabwe National Family Planning Council	--	--	--	1

APPENDIX 11

List of organisations within the Ministry of Lands, Agriculture and Rural Settlement, contributing to research in agricultural sciences (1980-2016)

Organisations	1980-1990 (n=148)	1991-1997 (n=133)	1998-2008 (n=166)	2009-2016 (n=77)
Ministry of Lands, Agriculture and Rural Settlement	--	1	2	--
Agricultural and Rural Development Authority (ARDA)	1	1	--	--
Chibero College of Agriculture	--	1	--	--
Department of Agricultural Technical and Extension Services (AGRITEX)	1	3	13	1
Department of Research and Specialist Services (DRSS)	72	69	75	55
Economics and Markets	--	1	--	--
Esigodini College of Agriculture	--	--	2	--
Grain Marketing Board	--	1	--	--
Institute of Agricultural Engineering	6	1	2	--
Livestock and Veterinary	45	49	65	15
Pig Industry Board	3	3	2	1
Save Valley Experimental Station	--	--	3	1
Tobacco Research Board	20	5	7	4
Zimbabwe Sugar Association Experiment Station	--	--	2	1

APPENDIX 12

List of Zimbabwean organisations within the Ministry `of Health and Child Care, contributing to research in social sciences (1980-2016)

Organisation	1980-1990 (n=8)	1991-1997 (n=9)	1998-2008 (n=13)	2009-2016 (n=15)
Ministry of Health and Child Care	1	--	2	7
Greenwood Park Eye Centre	--	--	--	1
Harare Central Hospital	1	--	--	--
Ingutsheni Hospital	--	--	--	2
Matebeleland North Province, Provincial Medical Directorate	--	1	--	--
Medical Research Council of Zimbabwe	--	--	--	3
Mutare Province, Provincial Medical Directorate	--	1	--	--
Mutare Provincial Hospital	--	3	2	--
National AIDS Council of Zimbabwe	--	--	--	2
National Institute of Health Research	4	2	5	1
Parirenyatwa Central Hospital	--	--	1	--
Zimbabwe National Family Planning Council	2	3	3	1

APPENDIX 13

List of international national organisations contributing to research in agricultural sciences, 1980-2016

International national organisation (INO)	Total number of articles	% contribution
International Maize and Wheat Improvement Center (CIMMYT)	156	41%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	92	24%
International Centre for Tropical Agriculture (CIAT)	36	9%
World Agroforestry Centre	23	6%
University of Florida/USAID/SADC Heartwater Research Project	14	4%
Center for International Forestry Research (CIFOR)	13	3%
Cirad - Zimbabwe	12	3%
Food and Agriculture Organization	9	2%
Seed Co - Zimbabwe	9	2%
Southern Alliance For Indigenous Resources (SAFIRE)	4	1%
Plan International	4	1%
PricewaterhouseCoopers (PwC)	3	1%
World Wide Fund (WWF) - Zimbabwe	3	1%
GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit	2	1%
United Nations Children's Fund (UNICEF)	2	1%
Linds Agriculture Services (Pvt) Ltd	2	1%
ABT Associates	1	<1%
International Development Enterprises (IDE)	1	<1%
Practical Action	1	<1%
Rockefeller Foundation	1	<1%
Intermediate Technology Development Group	1	<1%
Southern Africa AIDS Information Dissemination Service (SAfAIDS)	1	<1%
Forum for Agricultural Research in Africa (FARA)	1	<1%
Southern African Development Community (SADC)	1	<1%
Department for International Development (DFID)	1	<1%
WaterNet - Zimbabwe	1	<1%
Bayer in Africa	1	<1%
Agro Initiative Zimbabwe (AIZ)	1	<1%

APPENDIX 14

List of international national organisations contributing to research in health sciences (1980-2016)

International national organisation (INO)	Total number of articles	% contribution
World Health Organisation (WHO)	145	41%
United Nations Children's Fund (UNICEF)	23	6%
Population Services International (PSI)	21	6%
Centers for Disease Control and Prevention	21	6%
International Maize and Wheat Improvement Center (CIMMYT)	17	5%
University of Florida/USAID/SADC Heartwater Research Project	16	5%
Elizabeth Glaser Pediatric AIDS Foundation (EGPAF)	13	4%
Letten Foundation Research Center	12	3%
Cirad - Zimbabwe	12	3%
United Nations Population Fund (UNFPA)	8	2%
SolidarMed Antiretroviral Treatment (SMART) Programme	6	2%
Southern Africa AIDS Information Dissemination Service (SAfAIDS)	6	2%
Catholic Relief Services	5	1%
Institute of Water and Sanitation Development	5	1%
Institute of Public Health, Epidemiology and Development (ISPED) - Zimbabwe	5	1%
ABT Associates	5	1%
Medecins Sans Frontieres Doctors Without Borders	5	1%
Clinton Health Access Initiative	4	1%
Grassroot Soccer Zimbabwe	3	1%
Southern African AIDS Trust	3	1%
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	3	1%
Africare Zimbabwe	3	1%
International Union Against Tuberculosis and Lung Disease	3	1%
US Agency for International Development (USAID)	3	1%
GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit	2	1%
Japan International Cooperation Agency (JICA) - Zimbabwe	2	1%
Manicaland HIV STD Prevent Project	2	1%
United Nations AIDS Programme (UNAIDS)	2	1%
Regional Psychosocial Support Initiative (REPSSI)	2	1%
International Organization for Migration (IOM)	2	1%
Food and Agriculture Organization	1	<1%
Action Against Hunger	1	<1%
Tailjet Consultancy Services (TCS)	1	<1%
Southern African Development Community (SADC)	1	<1%
Salts Healthcare Ltd	1	<1%
Safe Blood Afica Project	1	<1%
Disability, HIV and AIDS Trust (DHAT)	1	<1%
Dudley Priority NHS Community Trust	1	<1%

JSI Research and Training Institute	1	<1%
Family Health International (FHI 360)	1	<1%
Practical Action	1	<1%
Helen Keller International (HKI)	1	<1%
Humana People to People's Total Control of the Epidemic (TCE)	1	<1%
RTI International	1	<1%

APPENDIX 15

List of national journals in Zimbabwe

Journal	Publisher	Coverage	Notes	Source
African Journal of Social Work	No information	No information	No information	https://www.ajol.info/index.php/sajest/about/submissions
Central African Journal of Medicine	University of Zimbabwe	Medical fields	No information	https://www.ajol.info/index.php/sajest/about/submissions
Dzimbahwe Journal of Humanities and Social Sciences (DJHSS)	Great University of Zimbabwe	No information	No information	http://www.gzu.ac.zw/journals/
Dzimbahwe Journal of Multidisciplinary Research (DJMR)	Great University of Zimbabwe	Multi-disciplinary research	First volume in 2016	http://www.gzu.ac.zw/journals/
Journal of Applied Science in Southern Africa (JASSA)	University of Zimbabwe	Multi-disciplinary, applied research considered important to the region	No information	http://universityjournals.org/journal/JASSA/about_jassa#targetText=The%20Journal%20of%20Applied%20Science,a%20multi%2Ddisciplinary%20science%20journal.&targetText=The%20journal%20publishes%20reviews%20of,main%20focus%20of%20the%20journal.
Journal of Social Development in Africa	No information	School of Social Work	Social development issues as they affect the poor and marginalized	https://www.ajol.info/index.php/jsda/index
Journal of Strategic Studies	Southern Bureau of Strategic Studies Trust	No information	No information	https://www.ajol.info/index.php/sajest/about/submissions
Midlands State University Journal of Science, Agriculture and Technology	Midlands State University	Science, Agriculture and Technology	No information	https://ww5.msu.ac.zw/home/research/university-journals/
Southern Africa Journal of Education, Science and Technology	Bindura University of Science Education (BUSE)	Agriculture, Commerce, Education, and Science	2006 to 2008; 2017	https://www.ajol.info/index.php/sajest/about/submissions
Southern African Feminist Review (SAFERE)	No information	No information	No information	https://www.ajol.info/index.php/sajest/about/submissions
The Dyke	Midlands State University	No information	No information	https://ww5.msu.ac.zw/home/research/university-journals/
Transactions of the Zimbabwe Scientific Association	Zimbabwe Scientific Association	Any aspect of science in Zimbabwe or the southern African region	Has ceased publication	https://www.ajol.info/index.php/tzsa/index
Zambezia	University of Zimbabwe	Humanities	No information	https://www.ajol.info/index.php/sajest/about/submissions

Journal	Publisher	Coverage	Notes	Source
Zimbabwe Journal of Applied Research	Lupane State University	Applied research in the fields of Agriculture, Commerce, Social Sciences and Humanities	First volume in 2018	http://www.lsu.ac.zw/the-zimbabwe-journal-of-applied-research/index.html
Zimbabwe Journal of Educational Research	No information	No information	No information	https://www.ajol.info/index.php/sajest/about/submissions
Zimbabwe Journal of Science and Technology (ZJST)	National University of Science and Technology (NUST	Basic and applied sciences, engineering and technology, clinical and computing sciences	No information	http://www.nust.ac.zw/zjst/
Zimbabwe Journal of Technological Sciences	Chinhoyi University of Technology	Technology as a developmental field in Africa	No information	https://www.ajol.info/index.php/sajest/about/submissions
Zimbabwe Law Journal	University of Zimbabwe	No information	No information	https://www.ajol.info/index.php/sajest/about/submissions
Zimbabwe Science News	Zimbabwe Scientific Association	No information	Nothing beyond 1999	https://www.ajol.info/index.php/sajest/about/submissions
Zimbabwe Veterinary Journal	Zimbabwe Veterinary Association	All aspects of animal health in Zimbabwe and SADC countries	This journal did not publish any issues between 2002 and 2015 but has been revived and and it actively accepting papers and publishing from 2016	https://www.ajol.info/index.php/zvj